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THE SERVICES OF NATHANIEL BOWDITCH TO AMERICAN ASTRONOMY.

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FOR POPULAR ASTRONOMY.

The series of articles on the study of physical astronomy may be appropriately continued by historical sketches of the careers of some of the great mathematical astronomers who established the scientific reputation of the United States, and laid the foundation of whatever is excellent in the history of American mathematics. Of the several great pioneers in the science of this country probably no other has rendered a service so illustrious and enduring as that of Dr. Nathaniel Bowditch, the celebrated translator and commentator on Laplace's *Mécanique Céleste*, who may justly be regarded as the founder of American mathematics and of American physical astronomy. Moreover the great excellence of Dr. Bowditch's character and his sacrifices in behalf of American science furnish an inspiring example of the highest type of scientific life, which ought to be better known and more appreciated in our time. We therefore gladly avail ourselves of an opportunity of rendering a pious tribute to this veritable disciple of Newton whose memory is worthy of every veneration.

In endeavoring to point out how Bowditch attained such great scientific eminence in the earliest years of the Republic, we shall rely for our information on the classic memoir, appended to the fourth volume of the Translation, by his son Nathaniel Ingersoll Bowditch, which gives a just and appropriate account of the life and work of one of the greatest and truest of American philosophers.

Nathaniel Bowditch was born at Salem, Massachusetts, March 26, 1773, the fourth of the seven children of Hubakkuk Bowditch, whose ancestors had lived in Salem from the earliest times. The family of Bowditch had preserved a long and honorable history, but had always remained in humble circumstances; the members of it were connected in various ways with the shipping business of Salem, as merchants, coopers and ship-masters. Dr. Bowditch's mother died in 1783, when he was but ten years old, but her exemplary character had already exercised a great influence on

the development of his youthful mind; and it is thought that the early and pious instruction of this affectionate mother laid the foundations of that inflexible integrity of character by which he was so distinguished throughout life. His father met with business reverses at the beginning of the Revolutionary War and never retrieved his fortunes, but remained in very reduced circumstances till his death in 1798. The family was thus brought up with very scanty opportunities; and the boys were early assigned to various trades as a means of livelihood. The brothers and sisters of Dr. Bowditch died at comparatively early ages, so that he outlived them all by nearly thirty years. Dr. Bowditch early displayed his unusual mental aptitude, and when at school mastered the most difficult problems with great rapidity. At the age of ten years he was taken from school into his father's cooper's shop, and two years later became an apprentice in a ship-chandlery shop in Salem.

He continued in this employment until he sailed on his first voyage in 1795; when not engaged in serving customers, he spent his time studying mathematics, for which he had very decided taste. In 1787 Dr. Bowditch heard from his brother William, who afterwards perished on a voyage at Trinidad, a vague account of a method of working out problems by letters instead of figures; and on securing the book was so much interested and excited by his first acquaintance with Algebra that he did not get the least sleep during the whole of the next night. His studies at this period were quite varied, and were further broadened by the liberality of Dr. Prince and Dr. Bently, the Unitarian clergymen of Salem, who placed their libraries at his disposal. The extensive scientific library of Dr. Richard Kirwan was captured in the British Channel by a privateer fitted out in Beverly, the town next to Salem, and when this valuable collection, containing among other precious memoirs the Transactions of the Royal Society, came to be the nucleus of the Salem Athenaeum, the books were of course accessible to our author, who made a manuscript copy of most of the mathematical papers, partly because he could not afford to purchase the works, and partly because he wished to impress their contents more thoroughly upon his mind than could be done by a mere perusal.

In 1790 Dr. Bowditch began the study of Latin, in order to read the *Principia* of Newton, a copy of which had been presented to him by Dr. Bently. He labored over the great masterpiece with care, and wrote many notes on the language which contained the propositions announced by Newton; it is said that he

had mastered the immortal *Principia* at the age of twenty one years. Though Dr. Bowditch had steadily labored under extreme difficulties, owing to his poverty, it is said that he never regarded the obstacles in his path as in any way a hindrance to his advancement, but rather that they stimulated his efforts and rendered his progress more sure and steady. Bowditch's life led him to the conviction that it is a great disadvantage to be born and educated in the midst of luxury and ease; and he is said to have frequently mentioned with approbation the remark of a distinguished French Mathematician (Lagrange) to a young student, in whom he had become interested but who had told him of his parentage and situation in life: "Ah! I am sorry. You are too rich. You must give up mathematics."

According to the traditions of his ancestors, Dr. Bowditch began his career as a sailor boy at sea; he made four long voyages between 1795 and 1804, during which he visited the Island of Bourbon, Lisbon, Madeira, Manilla, Cadiz, Batavia, Summatra, etc. Bowditch was always eager to teach those who desired to learn, and on the fourth voyage taught the crew how to take observations for determining the position of the ship at sea; when the Captain arrived safely at Manilla, after encountering a perilous monsoon, he was asked how he contrived to find his way, to which he replied "that he had a crew of twelve men, every one of whom could take and work a lunar observation as well, for all practical purposes, as Sir Isaac Newton himself, were he alive."

During these voyages Bowditch found much time for the study of mathematics and for perfecting himself in the French and Spanish languages. "He loved study himself," says Captain Prince, "and he loved to see others study. He was always fond of teaching others. He would do anything if one would show a disposition to learn. Hence all was harmony on board; all had a zeal for study; all were ambitious to learn."

Dr. Bowditch's great excellence of character deserves especial commemoration; a companion of his voyages says: "He never manifested any moral failings whatever; but was always remarkable for his strict principles of conduct, and for the utmost purity of mind and character, detesting anything of an opposite nature even in word. His feelings, indeed, were quick, and sometimes, though rarely, he was thought to give a quick utterance to them; but the excitement passed off in a moment." Another says:—"I have known Dr. Bowditch intimately for more than fifty years, and I know no faults. This may seem strange; for most of your great men, when you look at them closely, have something to

bring them down; he had nothing. I suppose all Europe would not have tempted him to swerve a hair's breadth from what he thought right."

In his early years Dr. Bowditch was given much encouragement to pursue his scientific career by Harvard University; in July, 1802, to his great surprise, he was given the honorary degree of Master of Arts. During the latter years of his life he was one of the seven individuals entrusted with the immediate management and control of the College; on his decease his associates in the Corporation of Harvard College state "that he so acquired the confidence of his contemporaries, as to be regarded as the pillar and the pride of every society of which he was an active member, the effect of which never failed to be seen and acknowledged by its prosperity and success," and that Harvard College "has derived great benefit from the extraordinary endowments he possessed and by which, in the exercise of his characteristic zeal, intelligence, and faithfulness, he ever sustained and advanced all of its interests."

Dr. Bowditch was admitted to the American Academy of Arts and Sciences in 1799; and from his pen came many valuable papers which enriched its Transactions. In 1829 he was elected President of the Academy, in succession to the illustrious John Quincy Adams, ex-President of the United States—a high honor which he continued to hold until his death, when his associates recorded of their late President: "It is the common fate of mankind to die and be forgotton. It is the privilege of the just and good to be associated in the remembrance with tender and grateful recollections. It is the destiny of minds gifted above the common lot, and acting beyond the common sphere, to involve in general regret the communities that have known their worth. It is thus, that on the present occasion, our sincere and general regret is necessarily mingled with the sadness of domestic affliction."

Dr. Bowditch was twice married, on the first occasion, in 1798, to Elizabeth Boardman, who died a few months later while her husband was at sea; on the second occasion, in 1800, to Mary, the only daughter of Johnathan Ingersoll, which is regarded as the most happy circumstance of Dr. Bowditch's life. Undoubtedly many of his great achievements in later years and the comfort and satisfaction requisite for such intellectual efforts were directly traceable to the warmth and ideal beauty of his home life; so great was his appreciation of Mrs. Bowditch's steadfast devotion and care for the family that he dedicated to her memory

his immortal Translation of the *Mécanique Céleste*. The descendants of this great man have since retained a very high and honorable place in the history of Massachusetts, and several of them have been or are now Professors in Harvard University.

The most celebrated work published by Dr. Bowditch in the early part of his career was the *New American Practical Navigator*. Though he did not regard this work as anything more than a "practical manual" which could hardly be expected to advance his scientific reputation, it came into universal use among English and American sailors and has well retained its place to the present time. It was by the *Navigator* that Bowditch first became widely known in this country, and the popularity of our author among seamen may be gathered from the fact that on his decease flags floated at half mast in the harbors of Baltimore, Salem and Boston, and at Cronstadt, when the sad intelligence reached the capitol of the Czars.

At the close of Dr. Bowditch's seafaring life, he was elected President of the Essex Fire and Marine Company, a position which he retained until he moved to Boston in 1823. During his residence at Salem he published numerous valuable papers in the Transactions of the Academy of Arts and Sciences: some of these papers bear on navigation, others relate to the orbits of comets, eclipses of the Sun, meteors, heights of mountains, variation of the magnetic needle; motion of the pendulum, solar tables, oblateness of the Earth, mistakes in the *Principia* and *Mécanique Céleste*, etc. Besides these papers he published others in Zach's *Correspondence Astronomique*, the *North American Review* and other journals of the highest standing. The article on the progress of modern astronomy in the *North American Review* for April 1825 is especially important to the critical student, and should in no case be overlooked. It consists of a sound and impartial historical criticism of the work of the great mathematicians who had preceded Bowditch, and each of the great masters here given the exact credit to which he is entitled.

We now come to speak of Dr. Bowditch's last and greatest work, the celebrated Translation and Commentary on Laplace's *Mécanique Céleste*. This work has undoubtedly had the greatest influence on the development of American Astronomy, since the proverbial difficulty of the *Mécanique Céleste* renders it almost inaccessible to beginners; and in our universities and colleges astronomy has never been given that thorough and systematic attention which is merited by the dignity and inherent importance of the subject. Our universities have too often labored under the

impression that the number of students in a given department is a just criterion of the importance of its educational work; the tendency has been to make the advancement of human knowledge subsidiary to *numbers* and *majorities*, just as if a multitude counted for anything in the discovery of scientific truth! It ought to be perfectly obvious that the development of a single man like Bowditch is of more importance *in the advancement of science* than perhaps all the other students in the college combined. As an example of this idea, we may cite the case of Gauss. His lectures at Göttingen were attended by very few students, his largest class in nearly fifty years numbering only thirteen, and yet by his works Gauss has become and will remain the teacher of all civilized countries during all succeeding ages. Laplace was professor of Mathematics and Astronomy at Paris, and yet only the least part of his influence was exercised during his lifetime. So also with Bowditch; he realized the importance of his work in time to come. Nearly all of our leading astronomers have been students of this great man, and the same is true of many of the astronomers of other countries.

Dr. Bowditch had read the successive volumes of the *Mécanique Céleste* as they appeared, and by the year 1817 had completed the Translation and Commentary on the first four volumes. The fifth volume, which Laplace did not publish until 1825, was never translated, owing to Dr. Bowditch's death, March 16, 1838; but as the last volume of Laplace relates chiefly to the history of Celestial Mechanics, to the earth's temperature and the velocity of sound, Bowditch's translation is nearly complete so far as the strictly astronomical matter is concerned. The notes were revised and brought up to date as the work came to the press in 1829, 1832, 1834 and 1839; Benjamin Peirce assisted in reading and correcting the proof, and he thus became the logical successor of Bowditch, who had early discovered his extraordinary talents. Our author's object in translating the *Mécanique Céleste* was to supply the steps which Laplace had omitted, and which rendered the original work inaccessible except to the most learned mathematicians. *The Edinburgh Review* in 1808 said:—"We will venture to say that the number of those in this island who can read that work with any tolerable facility is small indeed. If we reckon two or three in London and the military schools in its vicinity, the same number at each of the English Universities, and perhaps four in Scotland, we shall hardly exceed a dozen; and yet we are fully persuaded that our reckoning is beyond the truth." It is said that not one person in America, besides Dr. Bowditch,

had read the work critically, and not more than three would have been able to do so. The necessity of a Translation and Commentary was therefore obvious, and accordingly when the work appeared it was hailed with delight by astronomers in all the countries of the world. Dr. Bowditch was accustomed to remark that "Whenever I meet in Laplace with the words 'Thus it plainly appears' (il est facile de voir), I am sure that hours and perhaps days of hard study will alone enable me to discover how it plainly appears." Mr. Babbage in 1832 wrote to the translator: "It is a proud circumstance for America that she has preceded her parent country in such an undertaking; and we in England must be content that our language is made the vehicle of the sublimest portion of human knowledge, and be grateful to you for rendering it more accessible."

A second object of the translator was to continue the original work to the time of publication, so as to include the labors of those mathematicians who had improved upon some of the methods used by Laplace. Lacroix wrote in 1836: "I am more and more astonished at your continued perseverence in a task so laborious and extensive. I perceive that you do not confine yourself to the mere text of your author and to the elucidations which it requires; but you subjoin the parallel passages and subsequent remarks of those geometers who have treated of the same subject; so that your work will embrace the actual state of the science at the time of its publication."

Legendre in 1832 writes: "Your work is not merely a translation with a commentary: I regard it as a new edition, augmented and improved, and such a one as might have come from the hands of the author himself if he had consulted his true interests, that is, if he had been solicitously studious of being clear." Bessel in 1836 says: "Through your labors on the Mechanism of the Heavens Laplace's work is brought down to our own time, as you add to it the studies of geometricians since its first appearance. You yourself enrich the science by your own additions, for which especial obligations are due you." Sir John Herschel in 1830 wrote: "It is very gratifying to me to commence a scientific intercourse, which I have long desired, with the congratulations which the accomplishment of so great a work naturally calls for; and I trust that its reception by the public will be such (of which, indeed, there can be little doubt) as to encourage you to proceed to the publication of the succeeding volumes, and that you will be favored with health, strength and leisure, to enable you to complete the whole of this gigantic task

in the masterly manner in which you have commenced it. It is a work, indeed, of which your nation may well be proud, as demonstrating that the spirit of energy and enterprise which forms the distinguishing feature of its character is carried into the regions of science; and every expectation of future success may be justified from such beginnings." Encke in 1836 writes of it as a work "which, by the depth of the researches with which it is accompanied, will ensure to you a distinguished place among the astronomers who have employed themselves on the difficult branch of physical astronomy."

It will be seen from what we have said that Dr. Bowditch was moved only by the highest and most exalted motives, and this nobility of character and self-sacrifice appears perhaps still more clearly in the matter of the publication of this great work. The American Academy had generously offered to publish the work at their own expense, and the translator was also solicited to publish it by subscription; but these flattering offers were unhesitatingly declined, as Dr. Bowditch was aware from the nature of the subject that his readers would necessarily be few, and he did not desire to sell anyone a book which he could not read. The publication was therefore delayed for a number of years and finally completed from 1829 to 1839 at his own expense of over ten thousand dollars, which was one-third of the value of his entire estate. It is interesting and gratifying to know that in the recent edition of the works of Laplace, issued under the auspices of the Paris Academy of Sciences, some errors which Bowditch pointed out are corrected in foot-notes, and in several cases the editors, M M. Puiseux and Tisserand, close their remarks with "Voir l'edition de Bowditch;" they also refer to our author as "le consciencieux commentateur."

But though Dr. Bowditch's chief work was not published till towards the end of his life, his fame as a mathematician and astronomer had become fully established, and the high honors of science were showered upon him. He was elected a member of the Royal Society of Edinburgh in 1818; Royal Society of London in 1818; Royal Irish Academy in 1819; Royal Astronomical Society of London in 1832; Royal Academy of Palermo in 1835; Royal Academy of Berlin in 1836. He was equally honored in his own country, by being chosen to membership in all the learned societies of the time, and in 1816 at the annual Commencement of Harvard College he received the honorary degree of Doctor of Laws. In 1806 Dr. Bowditch was elected Hollis Professor of Mathematics in Harvard University, but this position was de-

clined owing to an unwillingness to break up his long connection with Salem. In 1818 he was offered a similar position in the University of Virginia by President Jefferson, who said in making the offer: "We are satisfied we can get from no country a professor of higher qualifications than yourself for our Mathematical Department." In 1820 Mr. Calhoun, the Secretary of War, desired to nominate Dr. Bowditch to the vacancy in the chair of mathematics at West Point; and said in his letter: "I am anxious to avail myself of the first mathematical talents and acquirements to fill the vacancy." In 1823 Dr. Bowditch accepted the position of Actuary to a Life Insurance Company in Boston, and from the income thus derived (which amounted to $5,000 a year) eventually found the means of publishing the Translation and Commentary. When Bowditch left Salem, a banquet was given by his fellow-townsmen, "To their respected guest, who reflected upon his country the brightest honors of science, and diffused in social life the warmest influences of benevolence." The wish was expressed that "he might enjoy a happiness as pure as his fame, and constant as the activity of his virtues," and it was declared that "as the Monarchy of France had done honor to her Laplace, so would the Republic of America not be ungrateful to her Bowditch."

During the latter years of his life Dr. Bowditch took much part in developing and extending the usefulness of the Boston Athenaeum. The trustees, on his decease, passed appropriate resolutions on his services to that institution and add: "But Dr. Bowditch has far higher claims to notice; he stood at the head of the scientific men of this country, and no man has contributed more to his country's reputation. His fame is of the most durable kind, resting on the union of the highest genius with the most practical talents and the application of both to the good of his fellowmen. Every American ship crosses the ocean more safely for his labors, and the most eminent mathematicians of Europe have acknowledged him their equal in the highest walks of their science. His last great work ranks with the noblest productions of our age." "But it is not merely the benefactor of this institution, and the illustrious mathematician, whose labors have given safety to commerce and reputation to his country, whom we lament. It is one whose whole life was directed to good ends; who combined the greatest energy with the kindliest feelings; who was the friend of every good man and every good undertaking; the enemy of oppression, the patron of merit, the warm-hearted champion of truth and virtue," etc. In like manner the

Salem Marine Society declared that "In his death a public, a national, a human benefactor has departed. Not this community, nor this country only, but the whole world, has reason to do honor to his memory. When the voice of Eulogy shall be still, when the tear of Sorrow shall cease to flow, no monument will be needed to keep alive his memory among men; but as long as ships shall sail, the needle point to the north, and the stars go through their wonted courses in the heavens, the name of Dr. Bowditch will be revered as of one who helped his fellowmen in a time of need, who was and is a guide to them over the pathless ocean, and of one who forwarded the great interests of mankind."

The reader will now be able to judge of the merits and virtues of the illustrious dead, whose glorious example ought to be of incomparable service in the advancement of American science. It is much to be regretted that the classic memoir by his son, from which we have drawn the foregoing material, is not available in pamphlet form. His influence on the scientific progress of this country during the last fifty years has been great beyond all computation, and wholly free from the spirit of self-seeking which is so characteristic of some of the smaller and more degenerate minds of our day. His favorite student was Benjamin Peirce, whose labors have shaped the development of American mathematics and of American physical astronomy.

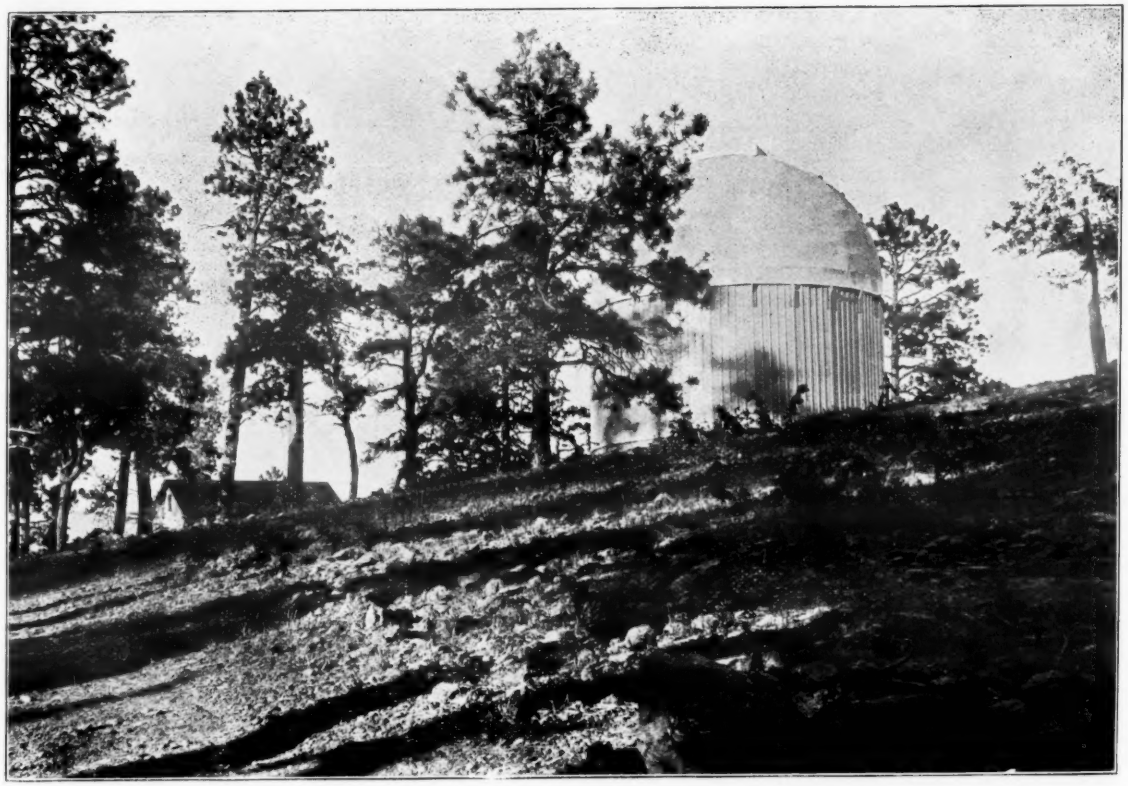
No greater mind has adorned this country than Nathaniel Bowditch, and the scientific world recognizes him, both for his intellectual and moral greatness, as one of the worthiest successors of the immortal Newton. Though Dr. Bowditch is dead, his imperishable example still lives, and will continue to inspire Americans as long as Science shall be cultivated on this side of the Atlantic. To this illustrious Founder of American Physical Astronomy let us dedicate a part of the just inscription on the tomb of Newton in Westminster Abbey:

"Mortals congratulate yourselves that so great a man has lived for the honor of the human race."

THE UNIVERSITY OF CHICAGO, April 7, 1895.

From a cutting in the *Cape Times* of March 4, we learn that there is a proposal under consideration to make the time of the meridian two hours East of Greenwich the Standard Time for the whole of South Africa. At present it seems that the standard time is exactly 1½ hours fast on Greenwich, in accordance with a resolution passed at the Bloemfontein Railway Conference in 1892, after somewhat hasty consideration.—*Observatory for April.*

PLATE XXVI.



RESIDENCE.

LOWELL OBSERVATORY DOME FROM SOUTH WEST.

FLAGSTAFF, ARIZONA.

THE LOWELL OBSERVATORY AND ITS WORK.

A. E. DOUGLASS.

For Popular Astronomy.

After briefly testing the general character of the atmosphere in several places in Arizona, Flagstaff, on the great plateau through which the Cañon of the Colorado finds its way, was selected. It is a trifle short of 7,000 feet above the sea and is ten miles south of the SanFrancisco Peaks whose highest point is 12,-800 feet in elevation. The Observatory is a mile north-west of the railroad station and three hundred and fifty feet above it on the extreme eastern edge of the "Mesa" (Spanish for "table") which extends a long distance west and north of the town. The whole country is covered with large pine trees save in the town itself. The townspeople from the first have been most generous to us not only in social courtesies but financially in giving a plot of land in the selected location and in building a road thereto, an item if no small expense.

The time occupied in building the dome and in mounting the 18-inch telescope was unusually short. The first ground was broken on April 23, 1894, and on June 1 regular observations on Mars were begun after a delay of several days due to cloudy weather.

Equipment.

The Observatory is supplied with a 6-inch, a 12-inch, and an 18-inch refractor (the two latter on the same mounting), photographic apparatus, eye-end appliances for the 18-inch, a dome, and a residence. The computing room or study, pertaining to the Obervatory is at present in the hotel near the center of the town.

The 18-inch Telescope.

The lens is by Brashear and has given great satisfaction during the time it has been in use. Its focal length is 315.5 in. The telescope is supplied with a micrometer and a good set of positive and negative eyepieces.

Among the special eye-end appliances may be mentioned: (*a*) A spectroscope kindly loaned us by Brashear, its maker, with a 60° prism of glass and a similar one of quartz. (*b*) A polariscope of the Airy pattern, which can be placed between the eyepiece and the eye. (*c*) Scales of canals used in measuring the width and density of the Martian canals. The first scales experimented with

Popular Astronomy No. 19. 1895. Flagstaff, Arizona.

were photographic reductions of India-ink drawings, but the scales which give most satisfaction were ruled on glass by Dr. Ewell, of Chicago. Each canal on the scale consists of fine lines ruled by a dividing engine, the width and density of a canal being at once accurately known by the number and spacing of the lines. (*d*) Comparison apparatus, constructed by Brashear from the design of Professor W. H. Pickering, by which one is enabled to bring two bodies, such as the Moon and a planet, into the same field at the same time. On the objective side of the eye-piece is a thin glass plate at an angle of 45°, casting into the eyepiece light which approaches through an arm at right angles and capable of motion about the optical axis of the telescope. A second mirror parallel to the first is placed in the outer end of this arm and can be rotated about the axis of the arm; by means of these two motions any part of the sky can be brought into view. Between the two mirrors is the objective of this secondary telescope. Besides the mere visual comparison which may thus be made, a specially constructed spectroscope may be attached in place of the eye-piece, or any other of the eye-end appliances except the micrometer, can be used. A second function of this comparison apparatus is to throw into view illuminated scales of canals or ellipses. This can be done by removing the second mirror and putting in its place the transparent scale with a light behind it, and replacing the small objective by one of shorter focus. The focus of the apparatus is always obtained by movement of the objective and the apparent size of the scale can be altered by changing the relative positions of the scale and objective. This apparatus deserves further application. By substituting two transparent lines for the scale a micrometer could be formed which has none of the disadvantages of opaque lines crossing the field; or, by means of a single open slit alterable by a micrometer screw, extremely small objects could be measured with the facility now pertaining to large ones alone.

The telescope is supported on one of the Clark mountings. In fact it is the same bed-plate and clock-work formerly used for the 13-inch Clark refractor of the Harvard College Observatory.* With an 18-inch telescope the mounting is somewhat unsteady yet not seriously so. Its chief objections seem to be the necessity of changing the driving sector every two hours, and the limited extent of slow-motion in right ascension. Control is effected by an independent pendulum clock and the spring governor. The

* The bed-plate and the 12-inch telescope are the property of that institution, being leased to Mr. Lowell.

PLATE XXVII.

FIG. 1. DOME FROM NORTH SHOWING SHUTTER.

FIG. 2. WINDLASS FOR RAISING SHUTTER.

PLATE XXVIII.

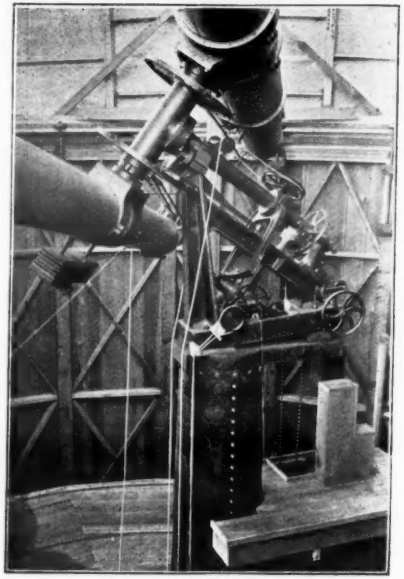


FIG. 2. MOUNTING.

FIG. 1. OBSERVING CHAIR.

pier of the instrument consists in two tubes of boiler iron, the lower one ten feet long and buried in the ground with cement nearly its entire length; the upper is fourteen feet long, projects some twelve feet above the floor of the dome and supports the bed plate upon its top. Of course no wood-work of the building is allowed to touch the pier.

The 12-inch Telescope.

This was made by Clark and if I am correctly informed was a model for Lick telescope. The figuring of the lens was never finished, however, and therefore its present use is entirely photographic. It is supplied with enlarging apparatus, and the residence contains a dark-room and all its accessories but since the commencement of the Observatory we have spent very little time at this work. It is mounted as a counterpoise on the declination axis of the 18-inch.

The 6-inch Telescope.

This is one of Clark's portable instruments and can scarcely be surpassed in beauty of definition. It was the instrument used in atmospheric tests in different parts of Arizona. Since then we have used it on various occasions and at present it is in town for the purpose of studying the difference in atmosphere between the hill and the valley.

Dome.

The lower part of the building is circular in section, and consists of twenty-four cedar posts set deep into the ground and well braced by horizontals and diagonals, the whole being covered on the outside with thin boards so that the interior quickly assumes the temperature of the outside air. The method of bracing it may be seen in the photograph of the mounting (Plate XXVIII, fig. 2). A live-ring of eighteen bevelled wheels running between hardwood tracks supports the dome proper. The stationary guide-wheels for the ring and the dome may be distinguished in the photograph. Above a frame such as described by Professor W. H. Pickering in *Astronomy and Astro-Physics* for January, 1894, is stretched wire netting, and on top of that well-painted canvas. The radius of curvature of the dome is seventeen feet. The revolving part weighs approximately three and one-half tons which is rotated by a block and tackle attached to the lower end of a post fastened securely to the dome and projecting downward to within three or four feet of the floor.

Shutter.

We consider the great size of opening in the dome an especially good feature. It is eight feet in width and extends from the sill to some four feet beyond the apex. The problem of suitably covering this area gave considerable trouble but the present shutter answers the purpose very well. It is simply a curtain of unpainted canvas, which lets down from the top, and it is stretched and held in place by wooden bars crossing outside and fastened only at the ends, as it appears in Plate XXVII, fig. 1. This allows rain to flow freely down the center. On each side of the opening is a track and outside that is a line of rollers which takes a large part of the weight of the curtain. A shoulder is made to project over the ends of the cross-bars to keep them from lifting outwards. Below all is placed a kind of box to receive the curtain when it is lowered, and inside is a rope for pulling it down in case it does not drop of its own weight. It is raised by means of two ropes which pass up at the side of the opening, cross the top of the dome, and descend beside the bar for turning the dome, passing thence round the windlass shown in Plate XXVII, fig. 2. In dry summer weather this shutter works admirably—it can be pulled up without the windlass. When wet it is necessary to use the windlass. But it behaves mischievously in winter when a foot of snow stands on it or when it freezes to the track as the snow melts—fortunate it is that snow storms are rare! But this could be prevented to a large extent by putting some kind of a covering over the sides of the curtain which would keep out the snow. Since those photographs, (Plate XXVII, figs. 1 and 2), were taken a moveable roof has been placed over the upper ten feet of the shutter when it is almost level. This roof can be slid backwards or forwards by ropes which descend to a cleat near the windlass.*

Observing Chair and Platforms.

When the dome was completed the floor proved too low for convenience. Accordingly an amphitheater-platform was constructed as shown in Plate XXVIII, fig. 1. This extends through an horizontal arc of over 200° and has its center due north of the pier; a space of three feet is left between it and the wall. The amphitheater consists of three steps which may be used as seats. Below these is a narrow flooring whereon an invalid chair enables the observer to work upon zenith objects in comfort.

* The shutter was devised by Mr. Douglas.—P. L.

Above the steps is a platform and a circular track upon which the observing chair moves. The chair itself has hinged seats, after the pattern given in Chamber's Astronomy, Vol. II, page 217.

The platform extending south of the pier which gives access to the clock-work and general machinery of the telescope has proved itself serviceable in every respect. The steps leading up to it have a slant of 60° from the horizontal. The top of the platform is of the width of the pier and cannot interfere with the movement of the telescope. A detachable extension is placed on one side to give easy access to the clock, sector, slow motion and clamp screws—shown in the accompanying plate, as are also the additional steps for climbing on top of the bed-plate. The hole for the driving weight to pass down through is shown beside them. The top of the platform has a slightly raised edge which enables the foot to feel its position. The plate also shows the east side of this platform and stairway. The opposite side gives entrance to the interior which is furnished with a closet, cupboard and the necessary shelves and drawers. The governing clock of the telescope is kept in the closet.

There is also shown a high staging which was built for a special purpose. At the top of the San Francisco peaks, nearly ten miles distant, is a canvas disc over four feet in diameter, put there at a known distance for the purpose of measuring the constants of the micrometer. When the telescope is pointed at the disc this staging is necessary to give access to the eye-end of the telescope.

Residence.

The description of the Observatory is practically completed by a brief mention of the residence. This building contains a study, two bed-rooms, a work-room and a dark-room. The slope of the hill is taken advantage of to put two rooms below—one intended for a bath room and the other used for storing wood. The building is warm and cosy in the coldest weather. It is situated one hundred feet north of the dome in order to interfere as little as possible with the seeing.

Work of the Observatory.—Mars.

The director's main purpose in building the Observatory was to study this planet and to that end the larger part of the time of the three observers has been devoted. The original plan of observation was to follow the development of the seasons, or any other changes and record them chiefly by means of drawings. In

the first three months, for instance, we made over two-hundred and fifty drawings of the full disc, besides many sketches of detail. At and before opposition in October measurements of diameters were regularly made, and in that connection observations on Polaris and daylight observations on the disc, previously mentioned, have been made to get the micrometer constants. Mr. Lowell has made careful measures of the longitudes of standard points to correct the ephemeris. Having tried both Schiaparelli's method of meridian passage and the ordinary method of locating a point by the micrometer, he prefers the former. The satellites have not been the subject of extended study, although at opposition they would obtrude themselves with Mars in full view when we were not expecting them. They were first seen here on September 10 when Mars' apparent diameter was 18″.7, and for some time a variability in their relative magnitudes was suspected but could not be confirmed. It was found afterwards that Professor E. C. Pickering in 1877 and '79 suspected variability. The last view was of Deimos alone on November 21st,* when the angular diameter of Mars was somewhat under 17″. A certain amount of time has been given to a search for other satellites with the usual negative results; of course really good nights were not used in this manner.

From the 30th of June to the 11th of September, 384 observations were made on the terminator, and, if the projections and depressions observed represent true differences in elevation of the surface, probably over one hundred mountains or valleys can be mapped from the data obtained. I have placed a conditional clause in the last sentence because the question does not yet seem satisfactorily settled. Irregularities of the terminator may be due to (*a*) permanent irregularities of surface, (*b*) clouds, or transitory objects of that character, and (*c*), contrast effects. The last head includes both irradiation and simple lack of reflecting power. While it seems unlikely that contrast has any real effect in producing irregularities (irregularities appear by daylight as well as at night) it has an influence, as shown by the apparent increase of the artificial projections and the decrease of depressions on the disc set up on the mountain. Our observations upon Mars are not merely of projections, as has practically been the case in previous oppositions, but there are fully as many depressions as projections—there may even be a predominence of them.

* Phobos is about 24 times brighter than Deimos.—P. L.

Interesting in this connection are the cloud-like appearances of September 25* and November 25 and 26.† Outside of these I have never seen anything that really suggested clouds except at the polar extremities of the disc. I think clouds or cloud-like objects on the terminator are extremely rare, and when they do appear can usually be recognized as such; yet if it can be demonstrated that they constantly appear over a given point it must be attributed to some physical nature of that locality more interesting than mere changes of elevation.

The doubling of canals on Mars has of course been a subject of special interest to us. Through October and November Mr. Lowell gave this his special attention and in November saw a number of double canals including Phison and Euphrates which had been suspected double in October. Mr. Lowell saw them double only in the best seeing, 8 or 10 on a scale of 10, and then they appeared like railroad tracks, straight and closely parallel. He found it an advantage to look for them at twilight or to use yellow glass at night.

Since opposition my attention has been almost exclusively devoted to what appear to be long straight canals traversing the dark regions of Mars. As long ago as November their study evoked a statement to the effect that the dark regions are interspersed with canals similar in length and straightness to those in the light regions, and whatever agency caused the one must have caused the other. Similarity is now recognized in width, length, straightness, abundance, direction, lakes at intersection and regularity of distribution. The dark regions seem to be due to a greater abundance of coloring matter darkening the canals and filling the spaces between them. The canals themselves appear to have a tendency to produce curiously symmetrical figures in their distribution.

Jupiter's Satellites.

These interesting bodies have been studied by Professor W. H. Pickering for some months. He has corrected the period of revolution on its axis of the 1st satellite (discovered by him at Arequipa, Peru) and now considers it known to within $0^{s}.2$.‡ He has also investigated the rotations of the other satellites and has made numerous drawings of detail, especially of the 3d. The other two observers, though not joining especially in this line of investigation, are both able to see the elipticities of these satellites.

* See *Astronomy and Astro-Physics*, November, 1894, Plate XXXII.
† See *Astrophysical Journal*, February, 1895.
‡ See *Astronomy and Astro-Physics* for November, 1894.

Powers Employed.

Professor Pickering has customarily used 1260 and 840 on the satellites of Jupiter. Mars has been subjected to various magnifications. When more than 16″ in apparent diameter 320 and 440 were used on him to increase contrast. Between 8″ and 16″ in diameter choice varied between 617 and 440. Under 8″, 860 has advantages. The lack of contrast at opposition was so marked as to preclude the use of powers above 440.

Meteorological Observations.

In addition to simple meteorological notes such as temperature, wind and cloudiness, observations of the atmospheric currents have been maintained on clear nights since the latter part of September. This is done by first placing the eye directly in the focus of the objective when turned upon some bright star—or planet of small diameter—and noting the wave-like appearances which cross the illuminated glass, and secondly, by turning the eye-piece outside the principal focus so that the height of a wave-system can be roughly determined by the extension necessary to bring it into view.*

Under this head and in conclusion may fitly come a word or two in regard to the seeing. The scale we use was devised by Professor W. H. Pickering (it is given in the article just referred to). From the beginning of last April until well through November the weather was good and the seeing for the most part eminently satisfactory. But during December and January it has been cloudy for weeks at a time and with scarcely an exception the few clear nights vouchsafed us have been conspicuously poor—heightening the contrast between the torrid and temperate zone atmospheres with which we are visited in turn, greatly to the disadvantage of the latter.

Lowell Observatory, Flagstaff, Arizona,
Jan. 30, 1895.

THE SPECTROSCOPE IN ASTRONOMY.

TAYLOR REED.

For Popular Astronomy.

Of star spectra there are three main classes:—first, spectra with few lines, but some extremely wide lines; second, spectra like that of our own sun; and third, spectra containing bands. The white

* I understand that this method will be published in full in the American Meteorological Journal for March.

or bluish-white stars as a rule give spectra of the first class; and as Sirius has a spectrum of this nature this class of spectra is often called the Sirian type. Yellow stars show spectra of the second class (our sun is probably yellowish). Some few red stars give spectra of the third or banded type. Stars are therefore classified from their spectra as white stars, yellow stars, and red stars; or often their spectra are said to be of the Sirian type, of the solar type, or banded. The Sirian type includes a little more than half of all the stars; conspicuous are Sirius, Vega, Altair, Rigel, Castor, Spica, Regulus. Stars of the solar type are a little less numerous; among them Capella, Arcturus, Pollux, Aldebaran. Of stars giving banded spectra there are but a few, and all are distinctly red; the brightest are Betelgeuse and α Herculis. A very few stars have peculiar spectra, which scarcely come under any of the main classes.

In spectra of the Sirian type the metallic lines, of which there are so many in the Sun's spectrum, are mostly faint or absent. And the hydrogen lines are usually enormously wide. The hydrogen lines vary both in width and in intensity. In some stars they are extremely wide; in others little wider than in stars of the solar type. In some stars the lines seem densely black; in some noticeably not black; and in two stars, γ Cassiopeiæ and β Lyræ, the hydrogen lines are positively bright. As for the other lines, in some stars scarcely any can be seen; and in some they are not radically less numerous and clear than in the solar type.

Among stars of the solar type are some like Capella whose spectra seem to be identical with the Sun's; others like Arcturus give spectra differing noticeably from the Sun's, though by the multitude and relative prominence of their lines still distinctly of the solar type.

Of spectra with dark bands there are two classes:—in most the bands are sharp and dark at the side toward the violet and shade out toward the red; in a very few (all faint) the bands are sharp toward the red. In addition to the bands dark lines appear. The violet end of such spectra is always relatively faint.

Half a hundred faint stars near the milky way give spectra containing bright lines or bands as well as dark lines. From the discoverers of the first examples they are usually called the Wolf-Rayet stars.

New stars or temporary stars (such as Nova Aurigæ) usually at their appearance give spectra with the usual number of dark lines, but the hydrogen, helium, and a few other lines bright. Within a year or so for no known reason, the spectrum is changed

utterly in character, so as to consist chiefly of one bright line in the green; the new star has become a planetary nebula.

Nebulæ give spectra of two classes. In one the spectrum is continuous, with no lines bright or dark. In the other there is a very faint continuous spectrum, and one very brilliant bright line in the green, together with a number of very faint bright lines, including lines of hydrogen; these nebulæ are therefore masses of shining gas under low pressure. Of the two great nebulæ the nebula of Andromeda gives a continuous spectrum, the nebula of Orion a bright line spectrum. The planetary nebulæ give bright line spectra. As to the nature of this principal nebular line there has been dispute; the majority of best observers see it as a line definite and equally sharp at both edges, not the remnant of a fluting. This line is almost certainly due to no known terrestrial substance.

The distribution of stars of different types in the sky is an important point in cosmogony. Stars of the solar type are distributed over the sky with substantial evenness. Stars of the Sirian type are much more numerous in the milky way. Are we therefore among solar stars evenly distributed in space, and in the center of a ring or disk of Sirian stars? Further, many solar stars and few Sirian have appreciable proper motions; showing that probably the Sirian stars are farther from us than the solar of equal brightness. Are the Sirian stars then larger than the solar, or brighter?

To deduce the state of a star from its spectrum is probably to guess rather than to reason. But the general belief is that a Sirian star is hotter than a solar and has a greater hydrogen envelope; that in all the characteristics of a Sun a Sirian star is yet more a Sun than our Sun. And most agree that the temperature of the red stars is not nearly so high.

Much work has been given to determining the motion of a star toward us or from us (that is, "in the line of sight") from the shifting of the lines in the spectrum toward the blue or toward the red. Such motion in a few stars may be known within a mile a second; for quite a number of stars it is probably known within five miles a second. It is found that the velocity of stars with reference to the solar system is not very different from the velocity already assumed for the Sun in space. A fair average is probably 20 to 25 miles a second. Few have velocities over 60 miles a second. In particular the motion of planetary nebulæ in the line of sight has been examined with the greatest spectroscopic power; and their velocities are comparable in amount with

stellar velocities. But great as are these velocities they have brought no star to us and carried none from us enough seriously to change its brightness, even since the earliest ages; as a little figuring will show.

Let a star be a close binary, with equal components, so revolving that we are in or near the plane of its orbit. When the line through the two components is directed toward us neither component is approaching us or receding from us. One-fourth of a revolution later the line through the components is perpendicular to the line from us to the star; one is then moving toward us in its orbital revolution, the other away from us. At this time the lines in the spectrum due to one component are shifted toward the blue, those due to the other component toward the red; that is, if the orbital motion is great enough, the lines of the star's spectrum are doubled. Now, this periodical doubling, indicating a "spectroscopic binary," has been observed in Spica, β Aurigæ, and Mizar (ζ Ursæ Majoris). The orbital period of such a binary is measured in days, and the two components must be so close that no telescope will ever separate them.

Let the variable star Algol have a smaller dark component which partially eclipses the bright. At eclipse neither is moving toward us nor from us. One-fourth revolution after eclipse the dark body is moving from us, and Algol toward us. One-fourth revolution before eclipse the dark body should move toward us, Algol from us. This motion of Algol from us before eclipse and toward us after eclipse should be seen in the displacement of lines in the spectrum. And this displacement has been detected. The spectroscope so seems to confirm the eclipse theory of stars of the Algol type. From this is derived our first serious estimate of the diameter of a fixed star. Assuming only that we are nearly in the plane of the orbit so that the eclipse is central, the measured velocities give:—for the diameter of Algol proper 1,000,000 miles; for the diameter of the dark companion 800,000 miles; for the distance between the centres of Algol and companion 3,200,000; orbital velocity of Algol 25 miles a second; orbital velocity of companion 54 miles a second; mass of Algol four-ninths that of the Sun; of the component two-ninths that of the Sun. This indicates that in magnitude Algol at least is of the same order as our Sun; and Algol is a Sirian star.

In these articles the attempt has been to state some of the results of spectroscopic work. Such outline must indicate the greatness of spectroscopic phenomena; but not their surpassing

beauty. And many of the most beautiful are well within the ability, experimental and financial, of the amateur.

In procuring a telescope, except where special work is selected for it, I think it sound judgment to sacrifice a trifle in size (not in perfection) of the telescope to procure spectroscopic accessories. Any equatorial telescope with clock-work can properly carry a solar spectroscope; and any one who can manage and care for such a telescope is equal to the manipulation of a solar spectroscope. The hardest part is the original adjusting, for which the beginner should insist on careful instructions from the maker. The cost will be about $200 or $250 for a small good one—avoid poor ones. The beautiful and varying solar prominences are better seen through such a spectroscope than through a very large one. And even the solar spectrum considered alone is a thing of beauty.

Any telescope, with clock-work or without, can have a small ocular star spectroscope sufficient to show the different types of stellar spectra magnificently.

As an adjunct a pocket terrestrial spectroscope is a most useful and delightful instrument, as well as cheap and portable (size of a cigar). With it you may examine anything in sight:—lightning, aurora, flames from volcanos, fire flies, the electric arc light, electric sparks with any electrodes, flame of Bunsen burner, and with some special forms of instrument meters if you are quick enough—here some valuable work should be done by amateurs as well as anybody else, in the meteoric showers soon due.

THE SOLAR EPHEMERIS.

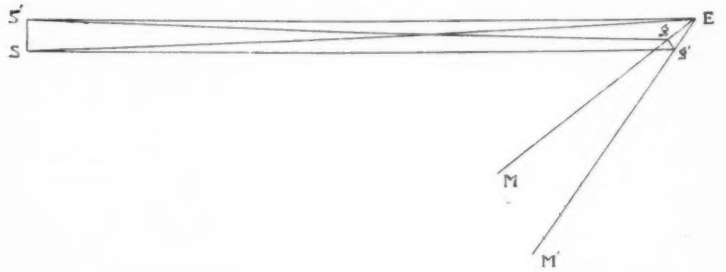
BY J. MORRISON, M. A., M. B., PH. D.

FOR POPULAR ASTRONOMY.

In the preparation of an ephemeris of the celestial bodies, that of the Sun holds the first place and has the most extensive application. Such an ephemeris is necessary for the determination of latitude and time at sea, as well as on land, and for the calculation of eclipses and of the local rising and setting of the Sun. The Sun's place in the celestial vault from day to day, is expressed in our Nautical Almanacs in two systems of coördinates, polar and rectangular. On page III of each month in the American Ephemeris and Nautical Almanac are given the Sun's longitude,

latitude and radius vector constituting a system of polar coördinates referred to the ecliptic as a fundamental plane and to two origins, viz., one the mean equinox of Jan. 1.0 which remains fixed throughout the year, and the other to the true equinox of date. The former is found to be most convenient in some of the more refined calculations such as the computation of orbits and perturbations. These coördinates are obtained directly from the solar tables for every fourth day and interpolated for intermediate dates, are fundamental in the solar ephemeris and constitute the basis for all subsequent computations relating to the Sun. The Sun's latitude is always very small; it is not deducible by direct observation but rests on theory; it is a function of, and has the same sign as, the Moon's latitude. It may be computed in the following manner:—

The Earth and Moon revolve around their common centre of gravity which point is situated within the Earth and always in the plane of the ecliptic. Conceive two planes one passing through the centre of the Sun and the centre of gravity of the



Earth and Moon and the other parallel to it and passing through the centre of the Earth. In the diagram let S', E and M' represent the Sun, Earth and Moon, g' the centre of gravity of the last two and g its projection on the latter plane, then we shall have

$$\sin \odot\text{'s lat.} = \frac{SS'}{ES} = \frac{gg'}{ES}, \text{ approximately}$$

$$= \frac{Eg}{ES} \sin \text{☽'s lat.} = \frac{M}{E+M} \cdot \frac{EM}{ES} \cdot \sin \text{☽'s lat.}$$

in which M and E denote the masses of the Moon and Earth respectively. But

$$\frac{EM}{ES} = \frac{\pi'}{\pi}$$

(π and π' representing the parallaxes of the Moon and Sun) and since

$$M = \frac{E}{81},$$

we shall have finally

$$\sin \odot\text{'s lat.} = \frac{1}{82} \cdot \frac{\pi'}{\pi} \cdot \sin \mathfrak{D}\text{'s lat.}$$

or expressing it in seconds of arc, we have approximately

$$\odot\text{'s lat.} = \frac{1}{82 \cdot \sin 1''} \cdot \frac{\pi'}{\pi} \cdot \sin \mathfrak{D}\text{'s lat.} \qquad (1)$$

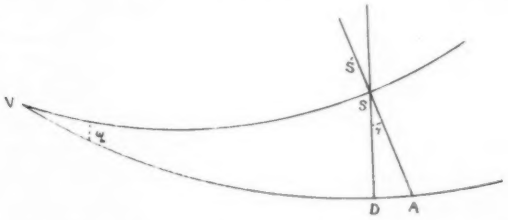
This formula will never vary more than 0″.05 from the truth and is accurate enough for all purposes. The effect of the planets is not here considered.

On pages I and II of each month we have another system of polar coördinates of the Sun referred to the equinoctial as the fixed plane and to the true equinox of date as the initial line; those on page II being given at equal intervals (Greenwich mean noon) and those on page I at unequal intervals; or at the moment of transit across the meridian of Greenwich. The latter are used at sea for determining the latitude. The Sun's R. A. and Decl. as given on pages I and II are deduced from the longitude and latitude given on page III, but most solar tables give an auxiliary table from which the R. A. and Decl. for both mean and apparent noon are given directly. The American Almanac gives the Sun's *true* longitude and the *apparent* R. A. and Decl. and therefore the former must be reduced to the apparent longitude before computing the R. A. and Decl. therefrom, by applying the aberration which is given on page 278, for every 10th day throughout the year. The true longitude always exceeds the apparent by the amount of the aberration, because we see the Sun not where he actually is but where he was some 8 minutes and 18 seconds ago. In the right angled spherical triangle formed by the apparent longitude (λ), the R. A. (α), the declination (δ), we shall have (ω being the apparent obliquity of the ecliptic) the following relations:

$$\begin{aligned} \tan \alpha &= \cos \omega \tan \lambda \\ \tan \delta &= \sin \alpha \tan \omega \\ \cos \lambda &= \cos \alpha \cos \delta \\ \sin \delta &= \sin \omega \sin \lambda \end{aligned} \qquad (2)$$

The second of the above is always to be preferred to the fourth for the reason that an angle is always determined more accurately from its tangent than from its sine. In these formulæ, the latitude has been neglected. When it is desired to take it into account, it can be done by first computing the angle between the circle of latitude and declination passing through the Sun's centre.

This angle varies from ω (the obliquity) at the equinoxes, to 0° at the solstices, and is computed thus: Let AV and VS represent arcs of the equinoctial and ecliptic respectively, V the vernal equinox,



SD and SA circles of declination and latitude passing through S the Sun's centre. Denoting the Sun's latitude by β, his longitude by λ, the obliquity by ω and the angle ASD by γ, we have from the right angled spherical triangle VSD

$$\cos VS = \cot \omega \cot VSD$$

or

$$\cos \lambda = \cot \omega \tan \gamma \qquad (3)$$

whence

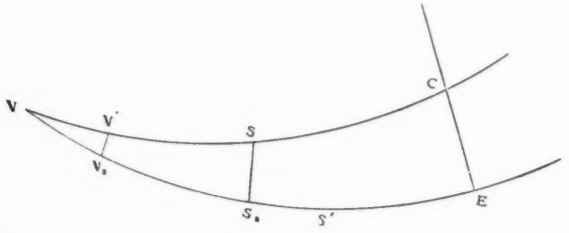
$$\tan \gamma = \cos \lambda \tan \omega$$

Now if the Sun has the small latitude $S'S$, then it is evident that the projection of $S'S$ or β on the circle of declination DS, or $\beta \cos \gamma$ is the correction to the declination, and of course $\frac{1}{15} \beta \sin \gamma \cos \delta$ will be the correction to the R. A., which however is almost inappreciable. Computors form a table giving the value of γ for every degree of longitude. In the application of these formulæ seven figure tables will be required to give the utmost degree of accuracy. The Sun's R. A. and Decl. for apparent noon, given on page I of each month, may be computed from those of mean noon by means of the equation of time as will be easily seen from the following example. Thus on Jan. 18, 1896, the equation of time at Greenwich mean noon is — 10 min. 34.47 sec., that is, apparent noon takes place 10 min. 34.47 sec. after mean noon. We must now find how much the Sun's R. A. and Decl. have changed during this interval and apply it with the proper signs to the R. A. and Decl. at mean noon; but the equation of time itself has changed slightly during these 10 min. 34.47 sec. and therefore we must first correct it and then compute the change in the R. A. and Decl. The variation of the equation of time in one hour on Jan. 18 is + 0.802 sec., hence the variation in 10 min. 34.47 sec. is + 0.141 sec., therefore the equation of time at apparent noon is + 10 min. 34.61 sec., which is tabulated on page

I in the column "Equation of Time, etc." During this time the R. A. increased by 1.88 sec., which added to the R. A. at mean noon gives $20^h\ 0^m\ 13.28^s$ the R. A. at *apparent* noon. The Decl. at apparent noon is found in the same manner.

The sidereal time at mean noon is found directly from the solar tables but it may be readily computed from the data already found. An example will best illustrate it. Thus, at apparent noon the Sun's R. A. is the sidereal time *at that instant*, and on the date we have selected, viz. Jan. 18, 1896, we have just seen that mean noon occurred 10 min. 34.61 sec. *before* apparent noon, therefore it is plain that if we convert 10 min. 34.61 sec. into *sidereal* time and subtract it from the R. A. at apparent noon we shall have the sidereal time at mean noon. By table III appendix we find 10 min. 34.61 sec. of mean time equal to 10 min. 36.35 sec. sidereal time, which subtract from $20^h\ 0^m\ 13.28^s$ the R. A. at apparent noon and we have $19^h\ 49^m\ 36.93^s$ which is the sidereal time at mean noon and tabulated opposite Jan. 18.

The Equation of Time is derived directly from the solar tables; it is given for both mean and apparent noon and is the connecting link between mean and apparent time. It arises from two causes, 1st, the unequal motion of the Sun in longitude and 2nd, the



obliquity of the ecliptic, each of which may be considered separately. In the diagram let VE be an arc of the equinoctial, VC of the ecliptic, V the *true*, V' the *mean* and V_2 the *reduced* place of the mean equinox, S the *true* and S' the mean Sun and CE an arc of a meridian of any place, then ES' (expressed in time of course) is the *mean* and ES_2 the *apparent* solar time, VS_2 is the right ascension of the true Sun, V_2S' the mean longitude (or R. A.) of the Sun and VV_2 "the equation of the equinoxes in R. A." The arc $S'S_2$ is the equation of time and from the figure we have

$$S'S_2 = VS_2 - VV_2 - V_2S'$$

or

$$S'S_2 = VS_2 - (V_2S' + VV_2)$$

that is, the equation of time is equal to the Sun's true right ascension minus the algebraic sum of the Sun's mean longitude (or R. A.) and the "equation of the equinoxes in R. A."

The mean longitude, which is of course equal to the mean R. A., is given in the solar tables and the "equation of the equinoxes in R. A." is given on page 278.

The equation of time is given only for apparent and mean noon, and for any other time we must take a proportional part, using second differences when the equation varies rapidly and when great accuracy is required. The part of the equation of time which is due to the 1st cause, vanishes twice a year, viz., when the Sun is in perigee or apogee, for then the *mean* and true longitudes agree; and the part arising from the 2d cause vanishes four times in the year, viz., at the equinoxes and solstices, for at these dates the difference between the Sun's longitude and right ascension is zero. By combining the effects of the two causes, it is found that the equation of time vanishes four times in the year, but these dates vary continually by reason of the change in the positions of the equinox and Sun's perigee which are separating from each other at the rate of about 61″.5 per year. The equation of time can be expressed in a series of sines of multiple arcs of the Sun's true longitude, from which series it can be easily computed. Thus if E denotes the equation of time in arc, λ the Sun's true longitude, p the longitude of the Sun's perigee and ω the longitude of the Moon's ascending node, the following series has been deduced:

$$\begin{aligned} E'' = {} & 461''.786 \sin (\lambda - p) - 593''.146 \sin 2\lambda \\ & - 2.907 \sin 2 (\lambda - p) + 12.793 \sin 4\lambda \\ & + 0.022 \sin 3 (\lambda - p) - 0.368 \sin 6\lambda \\ & + 0.099 \sin \omega + \text{planetary perturbations.} \end{aligned}$$

The coefficients are functions of the obliquity and the eccentricity of the Earth's orbit, both of which vary. The demonstration of this series is too difficult for insertion here and must be taken on credit, for we are writing not for the professed mathematician and astronomer but for students, amateurs and others who desire to extend their knowledge of astronomy, to gain admission to its sanctuary and to participate to some extent in the feelings and enjoyments of its votaries.

Before proceeding further we must digress to speak very briefly of the "Equation of the Equinoxes," which has been alluded to in the preceding pages, for it is of the utmost importance to the student that he acquire at the outset a clear and definite concep-

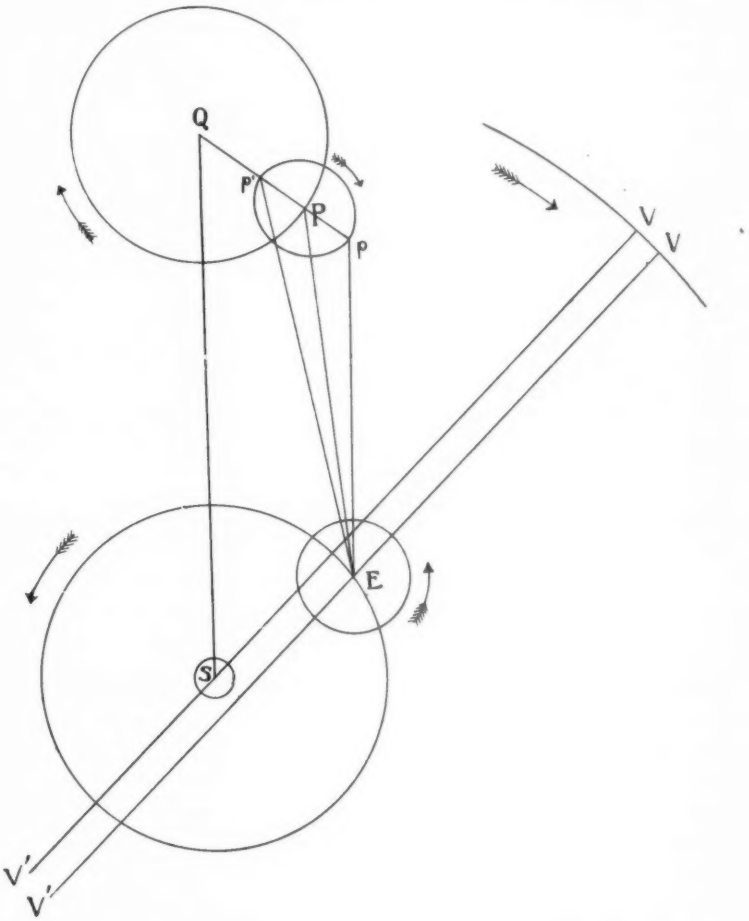
tion of the nature and use of the *five* astronomical corrections, viz., precession, nutation, aberration, parallax and refraction. The last one forms no factor in the construction of an ephemeris and as to the fourth, only the equatorial horizontal parallax of the Sun, Moon and planets is given. It is the basis for the computation of the parallax in altitude or zenith distance.

Precession and Nutation.

The longitude of the stars slowly increases from year to year while the latitude remains sensibly constant. This is due to a slow, gyratory motion of the Earth's polar axis in a retrograde direction and is caused by the rotary motion of the Earth and the combined action of the Moon, Sun and planets on the ring of equatorial matter in excess of the sphere of which the polar axis is the diameter. It is thus the resultant of two component motions. By the first of these the polar axis would describe in every 18.6 years an acute conical surface whose vertex is at the centre of the Earth, and whose intersections with the celestial sphere, form two equal ellipses whose transverse and conjugate axis are 18″.5 and 13″.7 respectively, the former being always directed to the pole of the ecliptic. By the second, the centres of these ellipses are carried uniformly around the poles of the ecliptic in a retrograde direction or from east to west in circles, whose radii are equal to the obliquity (about 23° 28′) and at a rate of 50″.2 in the interval of time between two consecutive returns of the Sun to the mean vernal equinox—which interval is the tropical year upon which our seasons depend.

In the diagram S represents the Sun, E the Earth, p the true and P the mean north pole of the equinoctial and Q the north pole of the ecliptic. The curve about S represents the Earth's orbit, and that about E the Earth's equator whose plane is always perpendicular to Ep; EV is the line of instersection of the planes of the equinoctial and ecliptic or the direction of the vernal equinox. The small circle about Q has a radius equal to the obliquity (23° 28′ nearly) and the curve about P is the elliptical path which the true pole p describes about P the mean pole. The transverse axis pp', of this little ellipse is always directed to Q the pole of the ecliptic. The arrows show the direction of motion. Let us suppose for the sake of illustration that the second component force ceases to act, then by the first acting alone, the true pole p would describe the small ellipse whose centre is P in every 18.6 years, the time required by the Moon's nodes to make one entire revolution; and again, if the first component

ceases to act, then by virtue of the second the mean pole P would be carried around Q in the direction of the arrow at the rate of 50″.2 per year. The change due to the first component or to the motion of the true pole in the small ellipse is called *nutation* and



that due to the second component, or the motion of P in the small circle about Q, is called *precession*. By the combined motions of nutation and precession the true pole p is carried with a variable motion along a gently waving curve whose undulations lie both within and without the circle described by P the mean pole, and which it intersects at points whose angular dis-

tances as seen from the centre of the celestial sphere are evidently equal to $9.3 \times 50''.2$ sin obliquity.

The equinoxes V, V' must always conform to the positions of the equinoctial poles and therefore have a slow, *irregular* and continuous retrograde motion.

The position of the equinox *without* nutation is the *mean* equinox; with nutation, the *true* or *apparent* equinox.

The inclination of the equinoctial to the ecliptic *without* nutation is called the *mean* obliquity; with nutation the *true* or *apparent* obliquity.

The difference between the *mean* and *true* or *apparent* equinox is the *nutation in longitude* and the difference between the mean and apparent obliquity is called the *nutation* of the obliquity.

The nutation is thus seen to be a correction to be applied to the *mean* equinox or obliquity to obtain the *true* or apparent equinox or obliquity.

In the *American Ephemeris* the nutation is called by the antiquated name of "the equation of the equinoxes in longitude." The *British Almanac* uses the proper and modern term "nutation" in longitude R. A., etc. The *American Almanac* does not give the nutation of the obliquity but gives at once (for every 10th day of the year on page 278) the apparent or true obliquity, *i. e.*, the mean obliquity corrected for nutation.

The nutation in R. A. is simply that of the longitude projected on the equinoctial and is found by multiplying the nutation in longitude by the cosine of the apparent obliquity. From the diagram it is easily seen that the apparent equinox deviates from the mean by a distance equal to the half of $13''.7$ which it reaches at the points where the little ellipse intersects the circle about Q and when the mean and apparent obliquity are equal; and the apparent obliquity varies on either side of the mean from zero to the half of $18''.5$ the maxima being reached at the points p, p' where the mean and apparent equinoxes coincide.

The changes here referred to are due to the action of the Sun and Moon and when estimated along the ecliptic are called lunisolar precession in longitude. By the action of the planets the Earth is slightly deflected from the path it would describe by the action of the Sun alone and the plane of the ecliptic is therefore changed but the amount of this change is exceedingly small, being only $46''$ in a century. At present its effect is to diminish the mean obliquity and this will continue for ages. The combined effect of all these bodies acting in the same direction, is the *general* precession in longitude.

[TO BE CONTINUED.]

PROBLEMS.

Solutions of the following problems will be acknowledged in subsequent numbers. They may be sent in on or before June 1st, to Professor Payne or to Dr. Morrison, Washington, D. C.:

1. If λ denote the Sun's longitude and E, the equation of time (in angle) due to the obliquity of the ecliptic, (ω) alone show that

$$\cot E = \cot 2\lambda - \cot \frac{\omega}{2} \operatorname{cosec} 2\lambda$$

2. Show that when that portion of the equation of time due to the obliquity (ω) alone, is a maximum

$$\cos^2 \delta = \cos \omega$$

where δ is the declination.

3. The times of Sun rise and Sun set on a certain day, are $6^h\ 54^m$ and $4^h\ 30^m$ respectively; find approximately the equation of time.

4. If the right ascension of a star is equal to its latitude, show that its declination must be equal to its longitude.

5. If E_m, in arc, denote the maximum value of the equation of time due to the obliquity alone, show that

$$\sin E_m = \tan^2 \frac{\omega}{2}.$$

6. Find the Sun's true longitude when that portion of the equation of time due to the eccentricity of the Earth's orbit alone is a maximum, the eccentricity being 0.016771.

7. The latitudes of two places on the Earth are complementary to each other and on a given day the Sun was found to rise 45 minutes earlier at one place than at the other, what is the latitude of each place?

LONG PERIOD VARIABLES.

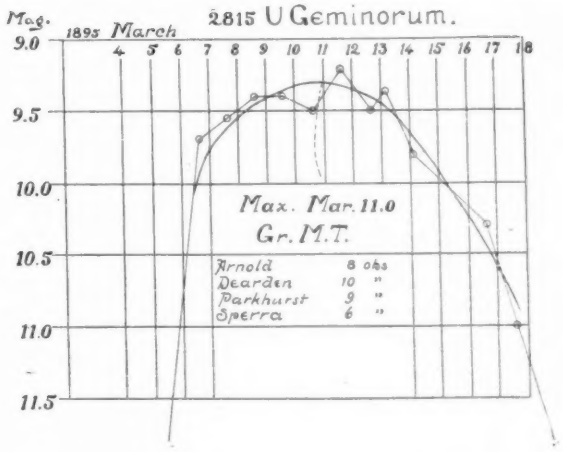
J. A. PARKHURST.

FOR POPULAR ASTRONOMY.

SUGGESTIONS FOR SPRING AND SUMMER WORK.

Several observers have informed me by private letters that they intend to begin work on variables this spring. I will therefore review the forty-two variables already charted in POPULAR ASTRONOMY, indicating the stars which will be available, the aperture which will be required to deal with them, and the particular ones in need of observation. The third column gives the number of POPULAR ASTRONOMY in which the variable is charted.

No.	Name.	Pop. Ast. No.	Aperture required Inches.	Remarks.
107	T Cassiopeæ	5	2 or 3	Max. due in Aug. Change slow.
320	U Cephei	7	2	Minima Apr. 10th, 15^h; 15th, 14^h; 20th, 14^h; 25th, 14^h; 30th, 13^h. May 5th, 13^h, 90th meridian time.
432	S Cassiopeæ	5	9	Min. due in Sept. Change slow.
814	S Persei	5	5 or 6	Min. due in May or June. Change slow.
243	U Cassiopeæ	17	3	Max. due in April. Quite red.
678	U Persei	15	6	Max. just past, star low at next min.
906	R Trianguli	15	6	Max. just past, star low at next min.
1113	U Arietis	4	5-7	Min. in morning twilight in June?
2478	R Lyncis	5	3	Max. due in July.
1805	V Orionis	15		Now near min. Next max. too near the Sun to be visible.
1855	R Aurigæ.	6	2-4	Now faint. Max. due in Aug. or Sept. when it will require morning observation.
2815	U Geminorum	7 and 9	3	Next max. too near the Sun.
3170	S Hydræ	17	6	Next min. too near the Sun.
3825	R Urs. Maj.	5	2 or 3	Now brightening. Max. due in June.
3890	W Leonis	9	4-6	Max. due in Nov. Will require morning observation in October and November.
4300	X Virginis	9	3	My obs. 1894 Mar.-June show no change.
4315	R Comæ	8	4-6	Max. due in July or early in Aug. Rapid rise. Becomes visible with 6 inches 6 weeks before max. Period uncertain.
4511	T Ursæ Maj.	5	2-3	Max. due in Apr. In good position for obs.
4557	S Ursæ Maj.	5	2-3	Max. due in July. In good position for obs.
4596	U Virginis	8	3	Max. due in May.
4805	W Virginis	7	4-5	Interesting. Short period. Obs. needed.
4816	V "	7	9-10	Min. due in May or June. Should be observed. No min. on record.
4492	Y Virginis	18	6	See next page.
4847	S "	8	2-3	Max. due in May. Obs. should begin at once.
5157	S Boötis	6	6	Min due in July. In good position for obs.
5190	R Camelopard	6	3	Max. due in June. In good position.
5194	V Boötis	8	3	Min. due in Aug. Should be observed.
5338	U Boötis	10	5	Max. in Mar. and Sept. Min. in June and Nov. Should be observed. Period changing?
5675	V Coronæ	7	3	Max. due in May. Very red. Change slow.
5955	R Draconis	6	3	Max. due in June. In good position.
6207	Z Ophiuchi	8	5	= B.D. + 1°.3417. Now near max. Min. in Sept? Should be observed.
7085	R I Cygni	10	3-4	Now near m'n. Change rapid. Should be observed.
7118	X Aquilæ	18	3	See next page.
7220	S Cygni	6	5	Max. due in July. Secondary maxima?
7609	T Cephei	6	2 3	Max. due in Sept. Change slow.
7779	S Cephei	6	4-5	Now near min. Very red. Difficult.
8324	V Cassiopeæ	15	6	Now near max. Next min. in July, in good position. Should be observed.
8600	R Cassiopeæ	6	2-4	Max. due in Aug. In good position at max.

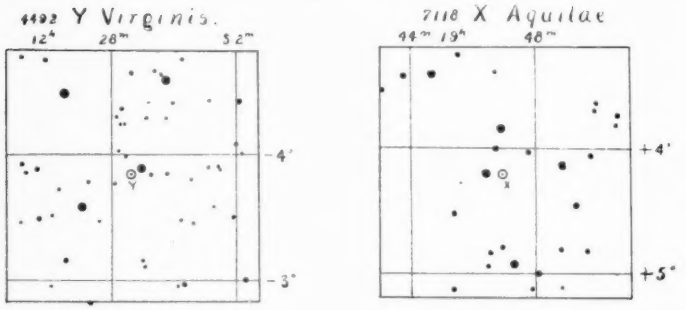


My request for observations of 2815 U Geminorum received a hearty response, and the maximum was well observed. The Moon was inconveniently near during the rise, which occurred on the 4th and 5th of March. The bright moonlight, lasting till the 12th made the observations more discordant than they would otherwise have been. Nevertheless, the results are very gratifying, and the accompanying light curve, based upon thirty-three observations, doubtless represents the variation closely. In locating the curve, the observations were united into daily means giving equal weights to each. The average deviation of the single observations from the mean curve is 0.12 of magnitude. The interval since the last maximum is 95 days, a little greater than usual.

Mr. Dearden's minimum of 1623 T Camelopardalis, 1894 July 16 was reported in Vol. II p. 215. I have 16 observations between 1894 Nov. 15 and 1895 Mar. 2, giving a maximum 1895 Jan. 8, so that the minimum preceded the maximum 176 days. The whole period is a few days over a year but as usual the rise is quicker than the decline.

Mr. Sperra obtained another minimum of 320 U Cephei 1895 Feb. 2, $13^h\ 49^m$ Gr. M. T.

Charts for two additional variables are given this month. 4492 Y Virginis was discovered by Henry in 1874, confirmed by Chandler. It has just passed a maximum but a minimum may be expected in July and should be observed by those using aperatures of 6 inches or more. Observations should begin soon. For



7118 X Aquilae see Vol. II, p. 216. It is now faint but a maximum may be expected in July and should be carefully observed as the period is not yet definitely known.

Place for 1900.

Star.	R. A. h m s	Decl. ° ′	Redness.	Magnitudes. Max.	Min.	Period. *d*
4492 Y Virgini	12 28 44	− 3 52.3	3.6	8 — 9.4	11.5 — 13	218.8
7118 X Aquilæ	19 46 32	+ 4 12.7	—	8	<12	351 ±

MARENGO, Ill., 1895, April 9.

MAKING ASTRONOMY POPULAR.

MARY PROCTOR.

FOR POPULAR ASTRONOMY.

To make astronomy popular, is by no means an easy task; but it is nevertheless becoming more and more popular every day. Books have been written on the subject, by such writers as Professor Ball, Garrett P. Serviss, Flammarion and my father, the late Professor R. A. Proctor, by means of which, the marvels of the heavens have been revealed to many who would not otherwise have become interested in the study. Then again, there are those who have not time to read such books; and for them, popular lectures on astronomy are provided. In an hour's talk, a lecturer is expected to condense enough material, to fill a volume. Yet much information can be given in this short space of time, but above all, such lectures usually inspire a desire for more; not more lectures, possibly, but for more information on the subject. Let me relate an experience. In New York, free lectures are given every Monday and Thursday night, at twelve grammar schools, and under the direction of the Board of Education. I

have already given two such lectures, and I have had most enthusiastic audiences; but the one I had not long ago, capped the climax. I received a note informing me that I was to lecture at a grammar school in one of the tenement districts of New York, and I must confess that I went in fear and trembling. I scarcely expected a dozen to attend the lecture. You may imagine my surprise, therefore, when I saw the people pushing and scrambling to get in, and policemen at the door to keep order. It was positively the roughest crowd it has ever been my pleasure to lecture to, and when I mounted the platform, and looked at the scene before me, I was almost overwhelmed. Nearly eight hundred people, mostly men, had crowded into the hall, and standing room was at a premium. I saw several policemen scattered here and there, and it seemed an utter impossibility to gain the interest of such an audience. And yet, from the moment my lecture began, till its close an hour later, not a sound was to be heard. I could *feel* that my audience was deeply interested, if not in my lecture, at least in the lantern slides, still I knew that they were listening to every word I said, because they never missed a point in the lecture. It may have been the very poorest who attended that lecture, but it was certainly one of the most attentive audiences I have ever had. Surely some in that crowded hall, must have felt a longing to know a little more about the wonders of the heavens, and if only one had such a desire, still I feel that my mission was accomplished. These free lectures under the direction of the Board of Education, reflect credit on the committee, and must surely prove a boon to those who are hungry for knowledge.

> Let knowledge grow from more to more
> That mind and soul, according well,
> May make one music as before,—but vaster.

PLANET NOTES FOR JUNE.

H. C. WILSON.

Mercury will be evening star during June, beginning the month nearest its greatest elongation east from the sun. There will be good opportunities during the first half of the month to see the planet with the naked eye. On the 8th Mercury and Jupiter will be in conjunction in right ascension, the apparent distance between them being less than one degree. On the 21st Mercury moving westward will again pass Jupiter, this time being 2° 34′ to the south of the great planet. At the end of the month Mercury will be very near inferior conjunction and so cannot be seen either by eye or with the telescope.

Venus will be the bright evening star, much brighter even than Jupiter, which she passed in May. She and the ruddy Mars will be in conjunction in right ascension June 4, Venus being then about one degree north of Mars. The moon will pass close to Venus on the night of June 25. As seen from the Pacific Ocean there will then be an occultation of the planet. The disc of Venus will be but slightly gibbous this month, since she is near greatest elongation east from the sun.

THE PLANETS AND THE ZODIAC FOR JUNE.

♈ = ARIES.	♌ = LEO.	♐ = SAGITTARIUS.
♉ = TAURUS.	♍ = VIRGO.	♑ = CAPRICORNUS.
♊ = GEMINI.	♎ = LIBRA.	♒ = AQUARIUS.
♋ = CANCER.	♏ = SCORPIO.	♓ = PISCES.

Mars is nearly in line with Venus, but twice as distant from the earth, as will appear from the diagram. They are moving eastward through the constellation Cancer and will pass close to the Præsepe cluster. Venus will skirt the north edge of the cluster June 13 and Mars will pass through the southern portion June 19-20. Mars will be in conjunction with the moon June 25, at 5 h. 27 m., a. m.

Jupiter is about in line with Mercury but from 6 to 9 times more distant than the latter. These two planets will be seen among the stars of Gemini. The new moon will pass them about noon on June 23.

Saturn will be seen in Virgo about 10° east from Spica, moving very slowly westward. He will be on the meridian early in the evening so that this month will be quite favorable for amateur observations. The plane of the rings makes an angle of 16° with the line of sight, so that they are readily seen as a single ring and in moments of good definition may be separated into two bright rings. Possibly also, those of our readers who have the better telescopes may be able to see the inner crape ring, which extends about half way from the inner edge of the bright ring to the surface of the planet. We are sure that you will be able to pick up three if not five of the satellites at times.

Uranus will be found to the east of Saturn, in Libra about 3° east and 1° south of the star α.

Neptune will be behind the sun June 6.

The Sun enters the sign ♋ and summer commences at noon June 21. Although the sunspot maximum is past, there are yet to be seen a goodly number of spots, enough to make the study of the solar surface interesting to the amateur.

Planet Tables for June.

[The times given are local time for Northfield. To obtain Standard Times for places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

MERCURY.

Date.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
June 5.....	6 37.5	+ 24 33	6 1 A. M.	1 41.5 P. M.	9 22 P. M.
15.....	7 1.5	+ 21 58	5 49 "	1 26.3 "	9 4 "
25.....	6 54.0	+ 19 29	5 14 "	12 39.5 "	8 5 "

VENUS.

June 5.....	7 58.5	+ 23 0	7 20 A. M.	3 2.4 P. M.	10 45 P. M.
15.....	8 44.4	+ 20 17	7 40 "	3 8.9 "	10 38 "
25.....	9 27.0	+ 16 51	7 59 "	3 11.9 "	10 25 "

MARS.

June 5.....	7 57.5	+ 22 5	7 24 A. M.	3 1.5 P. M.	10 39 P. M.
15.....	8 23.2	+ 20 44	7 17 "	2 47.7 "	10 19 "
25.....	8 48.4	+ 19 9	7 10 "	2 33.6 "	9 57 "

JUPITER.

June 5.....	6 44.8	+ 23 10	6 5 A. M.	1 48.8 P. M.	9 32 P. M.
15.....	6 54.2	+ 23 0	5 36 "	1 19.0 "	9 2 "
25.....	7 3.7	+ 22 47	5 8 "	12 49.2 "	8 31 "

SATURN.

June 5.....	13 59.8	− 9 25	3 37 P. M.	9 2.7 P. M.	2 29 A. M.
15.....	13 58.4	− 9 20	2 56 "	8 21.9 "	1 48 "
25.....	13 57.5	− 9 18	2 15 "	7 41.7 "	1 8 "

URANUS.

June 5.....	14 57.7	− 16 32	5 5 P. M.	10 0.4 P. M.	2 56 A. M.
15.....	14 56.4	− 16 27	4 24 "	9 19.8 "	2 16 "
25.....	14 55.3	− 16 22	3 43 "	8 39.4 "	1 36 "

NEPTUNE.

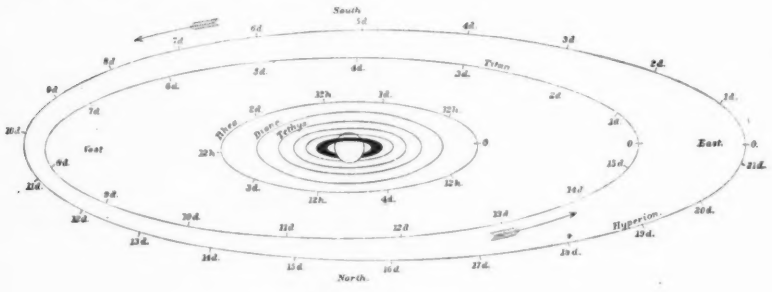
June 5.....	4 57.5	+ 21 16	4 28 A. M.	12 2.0 P. M.	7 36 P. M.
15.....	4 59.1	+ 21 18	3 50 "	11 24.2 A. M.	6 58 "
25.....	5 0.7	+ 21 20	3 12 "	10 46.5 "	6 20 "

THE SUN.

June 5.....	4 53.9	+ 22 35	4 17 A. M.	11 58.7 A. M.	7 40 P. M.
15.....	5 35.3	+ 23 20	4 15 "	12 0.2 P. M.	7 46 "
25.....	6 16.9	+ 23 24	4 17 "	12 2.4 "	7 48 "

Saturn's Satellites.

[E = east elongation; I = inferior conjunction (south of planet); W = west elongation; S = superior conjunction (north of planet). In the diagram the points of the orbits marked O are those of eastern elongation, as seen in an inverting telescope. The Central Standard times when the satellites will be at these points are given in the tables that follow The points on the orbits marked 1*d*, 2*d*, etc., indicate the places of the satellites at the intervals 1 day, 2 days, etc., after the time given for eastern elongation.]



I MIMAS. PERIOD 0*d* 22^h.6.

	h			h			h	
June 3	4.2 A. M.	E	June 11	4.5 A. M	W	June 20	3.4 A. M.	E
4	2.8 "	E	12	3.1 "	W	21	2.0 "	E
5	1.4 "	E	13	1.7 "	W	22	12.6 "	E
5	12.0 Mdn.	E	14	12.3 "	W	22	11.2 P. M.	E
6	10.7 P. M.	E	14	10 9 P. M.	W	23	9.8 "	E
7	9.3 "	E	15	9 5 "	W	24	8.4 "	E
8	7.9 "	E	16	8 2 "	W	25	7.0 "	E
9	6.5 "	E	17	6 8 "	W	26	5.4 "	E
10	5.1 "	E	18	5.4 "	W	29	2.3 A. M.	W
						30	12.9 "	W
						30	11.5 P. M.	W

II ENCELADUS. PERIOD 1*d* 8^h.9.

June 2	4.4 P. M.	E	June 12	6.6 A. M.	E	June 21	8.8 P. M.	E
4	1.3 A. M.	E	13	3.5 P. M.	E	23	5.7 A. M.	E
5	10.2 "	E	15	12.4 A. M.	E	24	2.6 P. M.	E
6	7.1 P. M.	E	16	9.2 "	E	25	11.5 "	E
8	4.0 A. M.	E	17	6.1 P. M.	E	27	8.3 A. M.	E
9	12.8 P. M.	E	19	3 0 A. M.	E	28	5.2 P. M.	E
10	9.7 "	E	20	11.9 "	E	30	2.1 A. M.	E

III Tethys. Period 1*d* 21^h.3.

June	2	9.2 A. M. E	June 11	7.7 P. M. E	June 21	6.2 A. M. E
	4	6.5 " E	13	5.0 " E	23	3.5 " E
	6	3.8 " E	15	2.3 " E	25	12.8 " E
	8	1.1 " E	17	11.6 A. M. E	26	10.1 P. M. E
	9	10.4 P. M. E	19	8.9 " E	28	7.4 " E
					30	4.7 " E

IV Dione. Period 2*d* 17^h.7.

June	1	2.9 A. M. E	June 12	1.5 A. M. E	June 23	12.3 A. M. E
	3	8.5 P. M. E	14	7.2 P. M. E	25	5.9 P. M. E
	6	2.2 " E	17	12.9 " E	28	11.6 A. M. E
	9	7.9 A. M. E	20	6.6 A. M. E		

V Rhea. Period 4*d* 12^h.4.

June	1	6.7 P. M. E	June 15	7.9 A. M. E	June 24	8.7 A. M. E
	6	7.1 A. M. E	19	8.3 P. M. E	28	9.1 P. M. E
	10	7.5 P. M. E				

VI Titan. Period 15*d* 23^h.3.

June	2	5.0 A. M. E	June 14	7.2 A. M. S	June 26	3.6 A. M. W
	6	1.9 " I	18	2.5 " E	30	4.7 " S
	10	6.1 " W	21	11.4 P. M. I		

VII Hyperion. Period 21*d* 7^h.8

June	1	1.8 P. M. E	June 12	12.2 P. M. W	June 22	7.5 P. M. E
	7	5.0 " I	16	12.0 midn. S	28	10.8 " I

VIII Japetus. Period 79*d* 22^h.0.

May 31	4.7 A. M. I	June 20	10.6 A. M. W	July 10	10.5 A. M I.

Phases and Aspects of the Moon.

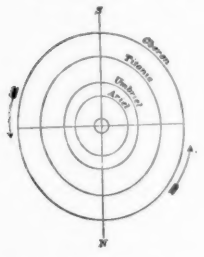
	Central Time.			
		d	h	m	
Full Moon	June	7	5	0	A. M.
Apogee		13	8	6	"
Last Quarter		15	5	28	"
New Moon		22	3	51	P. M.
Perigee		25	5	24	A. M.
First Quarter		29	8	1	"

Occultations Visible at Washington.

Date 1895		Star's Name.	Magnitude.	IMMERSION. Washington M. T.		Angle from N p't.	EMERSION. Washington M. T.		Angle from N p't.	Duration.	
				h	m	°	h	m	°	h	m
June	5	*b* Scorpii	5.3	10	25	81	11	39	321	1	14
	5	4 Scorpii	6.3	13	25	125	14	35	255	1	10
	5	π Scorpii	3.4	15	10	65	16	7	307	0	57
	12	42 Aquarii	5.8	18	43	359	19	33	282	0	50
	19	9 Tauri	7.0	15	6	137	15	24	177	0	18
	29	ψ Virginis	5.2	9	22	122	10	30	291	1	8
	30	85 Virginis	6.5	9	56	154	10	42	241	0	46

Satellites of Uranus.

[N = north elongation; S = south elongation]



Apparent Orbits of the Satellites of Uranus in 1895.

ARIEL. PERIOD 2*d* 12^h.489.

June	1	9.7	P. M. S	June	22	1.7	A. M. S
	3	4.0	A. M. N		23	8.0	" N
	4	10.2	" S		24	2.2	P. M. S
	5	4.5	P. M. N		25	8.5	" N
	6	10.8	" S		27	2.7	A. M. S
	8	5.0	A. M. N		28	9.0	" N
	9	11.3	" S		29	3.2	P. M. S
	10	5.5	P. M. N		30	9.5	" N
	11	11.8	" S				
	13	6.0	A. M. N				
	14	12.2	P. M. S				
	15	6.5	" N				
	17	12.7	A. M. S				
	18	7.0	" N				
	19	1.2	P. M. S				
	20	7.5	" N				

UMBRIEL. PERIOD 4*d* 3^h.460.

June	1	12.7	P. M. N	June	11	9.4	P. M. S	June	22	6.0	A. M. N
	3	2.4	" S		13	11.1	" N		24	7.8	" S
	5	4.1	" N		16	12.8	A. M. S		26	9.6	" N
	7	5.8	" S		18	2.6	" N		28	11.3	" S
	9	7.6	" N		20	4.3	" S		30	1.0	P. M. N

TITANIA. PERIOD 8*d* 16^h.942.

June	2	9.1	P. M. N	June	11	2.4	P. M. N	June	20	7.4	A. M. N
	7	5.9	A. M. S		15	10.9	" S		24	4.0	P. M. S
									29	12.4	A. M. N

OBERON. PERIOD 13*d* 11^h.119.

June	1	6.1	P. M. S	June	15	5.4	A. M. S	June	28	4.6	P. M. S
	8	5.9	A. M. N		21	11.0	P. M. N				

COMET NOTES.

Finding Ephemeris for Comet 1889 V.—In the *Astronomical Journal* No. 340 Mr. C. L. Poor gives the following ephemeris of comet 1889 V. This comet is the one which may possibly be identical with Lexell's comet of 1770. It will not be at perihelion until next year, but it is hoped that with some of the largest telescopes it may be picked up this year at the time of its opposition.

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1895	R. A.	Decl.	log Δ	Brightness.
	h m s	° ′		
May 2.5	15 31 24	− 23 47.7		
6.5	15 28 23	− 23 41.8	0.48055	0.05
10.5	15 25 17	− 23 34.9		
14.5	15 22 7	− 23 27.2	0.48056	0.06
18.5	15 18 55	− 23 18.7		
22.5	15 15 44	− 23 9.5	0.47728	0.06
26.5	15 12 37	− 22 59.9		
30.5	15 9 36	− 22 50.0	0.47673	0.06
June 3.5	15 6 43	− 22 39.9		

PRACTICAL SUGGESTIONS.

95. Do astronomers generally believe that the universe is limited in space or unlimited? L. H. B.

Answer: For the present astronomers have to say they do not know. There seems to be a slight preponderance of view in favor of a limited universe, but there are no known facts from observation to place the burden of proof on one side or the other.

96. What is the best book for celestial objects for common telescopes? F. H. B.

Answer: Among the best are:

1. The well known book, Webb's Celestial Objects for Common Telescopes. Last edition two vols.

2. A Cycle of Celestial Objects by Smith and Chambers. Second edition English.

97. What kind of naptha is used in cleaning object-glasses. F. H. B.

Answer: It is the mineral naptha of a volatile grade. The more rapidly it evaporates from the surfaces of the lenses the better. The reason for this will be readily understood.

98. What is the Right Ascension and Declination of the Pole of the Ecliptic? W. W. A.

Answer: The Right Ascension and Declination of the Pole of the Ecliptic is now approximately 66° 32′ 50″ and 18 hours or 270°.

99. In what work can I find a description of Dr. Henry Draper's figuring of his silver on-glass specula. P. MCC.

Answer: Dr Draper's work on the construction of a 15″ silvered glass telescope and its use in Celestial Photography can be purchased from the Smithsonian Institution. The price is $1 00. Address Secretary Smithsonian Institution, Washington, D C. J. A. B.

100. What is Foucault's test for concave surfaces. P MCC.

Answer: An abridgement of Foucault's methods is given in Dr. Draper's work which is ample for practical work.

Foucault's mother published his memoirs in the French language. There are two volumes, but they contain a large amount of matter not connected with his researches in optics. The publishers are Gauthier Villars et Fils, Paris. The price of the book is $9. J. A B.

101. Where can one purchase glass discs suitable for making specula. P. MCC.

Answer: The third question is more difficult to answer. For mirrors heavy plate glass such as is used for the port holes in ships may be had from Heroy & Marrenner or other dealers in plate glass, New York.

For mirrors of 10″ and up to 24″ I presume Geo. A. Macbeth Co., Pittsburg, Pa., can supply them. For larger discs the St. Gobain factory, on the Campagnie des Glaces & Verres Speciaux, Jeumont; both in France, are the best makers. J. A. B.

102. Who made the so-called Durchmusterung star catalogues? P. A.

Answer: Of the Bonner Durchmusterung the northern sections were published by Argelander between the years 1846 and 1867. Of the southern sections Schonfeld did later work. Other astronomers have also participated in these star surveys.

103. Where can I obtain R. A. Proctor's Chart of 324,000 stars based on Argelander's Durchmusterung?

Answer: We are not aware that Mr. Proctor ever published such a chart or catalogue of stars. Has our querist wrongly applied Mr. Proctor's name to Argelander's Durchmusterung of the northern heavens which contained more than 324,000 stars. This number is commonly used in connection with this catalogue.

104. **Carlyle and the Constellations.**—In Carlyle's History of the French Revolution he is describing the scenes of the ninth of August 1792. He says: "The night is beautiful and calm, Orion and Pleiades glitter down quite serene." That sounds well enough. I have no objection to the pleasant weather. But a question rises. Am I all wrong in my reckoning, or is Carlyle taking too much liberty with the zodiac in pulling it around so that Orion and the Pleiades shall look down upon the streets of Paris in an August night? It occurred to me that this touch from a great literary artist might amuse you, and that I might get from better authority than the Scotchman a solution of my puzzle. E. H. A.

Will some student of the constellations say whether or not the Scotchman is right?

GENERAL NOTES.

We can supply in pamphlet form, all numbers or volumes complete of POPULAR ASTRONOMY or *Astronomy and Astro-Physics*. We also have a few more complete sets of the *Sidereal Messenger*. It should be remembered that these publications furnish a continuous review of astronomy for the last fourteen years.

It doubtless has scarcely occurred to our subscribers that we are so near the end of volume two of this publication. The next number closes another year of this work and delightful study of elementary astronomy. We call attention to this fact so early that we may arouse and extend a new and wider interest in it for the immediate future. The theme is worthy of it, our readers ought to have more and broader help in its study and we ought to have a larger field of support in order to accomplish these two things during the coming year. Give some aid in extending the circulation of this magazine if it is worthy of it.

The Columbia College Observatory exhibited its new micrometer measuring machine by Repsold of Hamburg, and several recent instruments by Saegmuller.

A number of photographs of the solar corona and the Moon from the Lick and other observatories, were also shown.

More than fifteen hundred persons were present and an amount of interest in the exhibits was displayed that was highly gratifying to those who had charge of the reception.

The committee of arrangements and of reception, were: Wm. C. Hallock, Fred S. Lee, J. K. Rees, Bashford Dean, C. F. Cox, J. F. Kemp, N. L. Britton.

Mr. C. A. Post had charge of the department of astronomy.

Refractors and Reflectors—We have noticed that some interest and a little feeling are manifested over late references in these pages to the comparative merits of the two kinds of telescopes. It has seemed to us that some statements made by the friends of refractors and also by those favoring reflectors were not carefully considered before they were written or they would not have appeared exactly as they were given. Observers of experience in the use of both kinds of good instruments know very well that each kind has its strong points and its weak ones; and the skilled observer never quarrels with his instrument, for he knows what it can do and what it cannot do. As a valued correspondent, in a recent private letter, well says, the telescope is the means and not the end in astronomical work; and in the same connection he quoted Bessel's famous remark that a practical astronomer would make observations of value, if he had only a cart-wheel and a gun barrel; and the saying of Watson, that the most important part of the instrument is the man at the small end. In all this it should not be supposed by our readers that we undervalue large and elaborately mounted telescopes with luxuriously appointed observatories. Such are often the arbiters of astronomical questions that can be settled nowhere else. Nothing is too costly for the truth that the world now most needs.

In the beginning of December last I looked carefully for *Omicron Ceti* in the vicinity of the three stars of seventh magnitude with which it forms a trapezium.

Up to December 3rd it had not developed sufficient lustre to be identified, and having no circles on the four inch telescope used, I was uncertain which of several stars of ninth and tenth magnitude might contain the smoldering fires of the renowned variable. Weeks of rain and cloud intervening, a successful observation was not taken until the evening of December 31st, when "Mira" was at first glance identified as a star of eighth magnitude or slightly fainter than A in the pair 66 Ceti which is classed as seven and a half and is conveniently near for comparison.

The marvellous orb was now visible in an opera glass.

On January 14th and following days it had advanced to the same magnitude as A, 66 Ceti.

January 18th it was of seventh magnitude and a few nights after during a very clear interval was just discernable to the naked eye.

January 26th it had increased to sixth magnitude and was easily seen. February 7th it was of fourth magnitude and when the Moon had waned its pent up fires were kindled into the blaze of a star of third magnitude.

It was slightly brighter than Alpha Piscium and strangely different in tint from that Sirian orb.

The ruby light that flashed conspicuously from its mingled hues heralded its claim to a star spectrum of the third type which is numbered only in hundreds among the millions of Sirian and solar orbs.

Though it had decreased in light towards the middle of March, on the 22d it was still brighter than Alpha Piscium and more readily seen in the twilight which will soon hinder further observations of this interesting variable.

ROSE O'HALLORAN.

San Francisco, March 23rd, 1895.

The New York Academy of Sciences held its Second Annual Reception and Exhibit of Recent Progress in Science, on the afternoon and evening of March 13th, 1895, at the Fine Arts Building, 57th Street near Seventh Avenue.

Last year the Reception and Exhibit was given in the Library Hall of Columbia College. The exhibits were so numerous and interesting that it was found necessary, this year, to provide larger accommodations. As far as possible a separate room was devoted to each Science. The Department of Astronomy was particularly interesting. This was largely due to the fact that Professsors Barnard and Keeler each sent a very interesting series of photographs selected from their recent work.

Professor Barnard contributed twenty-three beautiful positives on glass made by himself from his negatives of the Milky Way, and also a series showing the Comets, Holmes, Gale, Swift and Brooks. Each photograph was viewed through a six inch magnifying lens of about 10 inches focus, a powerful electric light being transmitted through a thin screen of white porcelain placed behind each plate.

Professor Keeler exhibited a series of stellar spectra, taken with a visually corrected object-glass. The spectra were remarkable for the number of lines shown and for definition. They were seen to great advantage in a series of simple microscopes, the light from the reflector being diffused by a porcelain screen under each plate.

Dr. S. C. Chandler presented a number of charts showing variations of latitude at several parts of the Earth's surface and Professor John K. Rees exhibited a chart showing the results of a preliminary reduction of the observations made at the Columbia College Observatory during the years 1893-1894.

Some very perfect photographs of lightning were shown by Mr. Samuel Bridgham, and Mr. Charles A. Post exhibited, from his private observatory, a number of interesting photographs of the recent Lunar Eclipse of March 10th, as well as a number of positives, from a series of fifty negatives taken during the recent transit of Mercury.

A star spectroscope of large size by Mr. John A. Brashear, was much admired. The arrangements for the convenience of the observer, both photographic and visual, embodied all of the most recent improvements, and notwithstanding the great rigidity and stability of all of the parts, the weight of the entire instrument did not exceed 35 pounds.

May Aurora —The next return of the most prominent auroral series now in progress at the 27¼ day interval will be due on May 7, 8, 9. A lesser series is due on the 15th. It is suggested that those who have the requisite facilities study the condition of the Sun on these dates with reference to the location of spots at the eastern limb or elsewhere, and likewise if possible the spectroscopic appearances. The presence or absence of the aurora will be recorded by observers coöperating in many localities, and memoranda concerning the distribution of Earth currents on the telegraph lines and records of magnetic storms will be had for the purposes of comparison. Any information bearing upon any of these points may be communicated to the writer so that it may be summarized and placed within reach of all coöperating and others.

The return of the series on April 9th to 12th had been announced in advance to about two hundred observers, and as the result much interesting information was secured. It was characterized by commingling of thunderstorms and auroras the former being the most extensive on April 9th and the latter on April 11th. On April 10th and 11th especially there was considerable disturbance of the magnets at the Naval Observatory. M. A. VEEDER.

The Diameter of Neptune.—E. E. Barnard has recently published in the

Astronomical Journal (April 9, 1895) an article on the diameter of Neptune that brings out an interesting result. Ten measures of the diameter of the planet made with the great 36-inch equatorial at Lick Observatory, between Nov. 18, 1894 and March 4, 1895, give as a mean 2″.433. At a mean distance from the Sun this gives for the actual diameter of the planet a distance of 32,900 miles. The mean of best measures between 1846 and 1872 was 2″.611. That by Hermann Struve with the 30-inch Clark equatorial of Pulkowa from three sets of measures with different kinds of illumination of micrometer field was 2″.197. It will be seen that Mr. Barnard's results are between the two.

Supposed Discovery of the Calendar of the Mound Builders.—In a number of the Lyons *Republican*, published Feb. 22, 1895, Mr. Veeder of Lyons, N. Y., has an article entitled "Pre-historic Man." which calls attention to a curiously engraved stone that has marked upon it the supposed calendar of the ancient Mound Builders. The stone was found in a large mound in Cincinnati with other relics of interest. Its size is reported to be 5 inches long, 2.6 inches across the middle and 3 inches at the ends and can be easily held in the hand. A cut and a description of it will be found in Wilson's Pre-historic Man. Mr. Veeder thinks that this stone has engraved upon it a method of keeping time as it was recorded by the Mound Builders. His reasons are fully given in the paper above referred to.

After some correspondence with able scientists in Ohio about this matter, it seems to us that Mr. Veeder's reasons are not sufficient to raise a probability that his theory is correct.

1. Because the stone has no authentic history.

2. Because frauds of the same kind have been committed in Ohio before. More than 30 years ago, a regularly marked stone was professedly found in large ancient works at Newark, 35 miles east of Columbus. Its markings caused it to be sent from city to city, from one learned society to another,—it was read as Phenecian, Chaldean, Coptic, Hebrew and some other languages—proved this, that and the other, and excited this whole side of the continent. It turned out to be a fraud, manufactured and duly stamped so as to deceive the "very elect." When the fraud was known it caused a great deal of merriment.

3. Persons who have followed the work that has been done in trying to decipher hieroglyphic records know something of the extreme difficulty of such a task. Such knowledge makes interpreters exceedingly cautious in assigning meaning to forms they know so little about.

Stonyhurst College Observatory.—The annual report of the results of meteorological and magnetic and solar observations for 1894, made at Stonyhurst College, England, by Rev. Walter Sidgreaves, S. J., is received and is a neat little volume.

Wolsingham Observatory Tow Law.—From T. E. Espin's report for 1894 we gather the following facts:—

The total number of objects observed is 1044; of these, 498 are new objects. The large number discovered has caused their publication to take the same form as last year. Only 112 stars have been included in the principal list, and the others have been simply announced. Several new fourth type stars have been detected. On account of the increasing number of suspected variables, some time has been devoted to careful estimation of their magnitude. 57 stars are

under observation for variation, and 249 comparisons have been made of these. Seven new variable stars have been detected in the course of the year.

During the earlier part of the year, the proofs of the second volume of "Celestial Objects" have been passed through the press.

The Recent Opposition of Mars.—A summary of the work done by astronomers at the recent opposition of Mars is well stated in February number of the *Monthly Notices*, as follows:

1. The complete disappearance of the south polar spot as a visible object.

2. Numerous observations of irregularities at the terminator of the planet when it was gibbous, consisting of (*a*) small bright projections, usually in connection with a bright region just within the terminator. (*b*) Flattenings or slight hollowings of the curve of the terminator, generally at those parts where the darker regions were passing out of sight.

3. A very general confirmation of the canal system of Schiaparelli.

4. The duplication, or gemination, of a number of the canals, even at about the time of the summer solstice of the southern hemisphere.

5. Further extension of the work of Schiaparelli by the detection, chiefly at Mr. Lowell's Observatory, of many additional canals and other delicate details and of a number of minute dark spots or lakes, the latter often being curiously situated at the points where two or more canals meet or cross each other.

6. One of the most important results of the past season is certainly that relating to the presence of cloud. During recent years the opinion seems to have been gaining ground that the atmosphere of Mars is almost free from clouds, and that even when visible they are not of any great extent or density. But during the latter half of October last nearly the whole of the Maraldi Sea, and the extensive continental area extending north of it up to about 20° north latitude, were densely obscured by cloud, the region affected having an area of at least 6,000,000 square miles, considerably greater than that of the whole of Europe.

7. Additional evidence in favor of actual change. For instance, the disappearance of a considerable part of the bright region named Aurea Chersonesus has been independently noted by several observers, the continental outline here being much changed from what it was in 1877, according to the maps of Mr. Green and Professor Schiaparelli.

8. Professor Campbell undertook some observations of the spectrum at the Lick Observatory, but did not succeed in confirming the earlier observations of Huggins, Rutherfurd, Vogel and others in finding evidence of absorption due to an atmosphere.

The Number of the Asteroids.—The volume of the *Berliner Astronomische Jahrbuch* for 1894 gives the number of asteroids, of which observations enough were obtained to determine their orbits as 390. Number 390 was designated in order of discovery as 1894 BC. Since that list was compiled 19 more have been discovered, the last being 1895 BW, discovered by Charlois at Nice, March 21. Not all of these have been observed a sufficient number of times to determine their orbits and some have been identified with previously discovered asteroids. We cannot tell just how many will receive permanent numbers; but the total number is now certainly over 400.

Transit for 1894.—The transit of Mercury in November 9-10, 1894, was very generally observed. But little, however, as far as we are able to learn, that

is new has resulted from the observations. Mr. Barnard's article in the *Astronomical Journal* of Jan. 23 is interestingly full of details and known facts pertaining to observational work. Astronomers hoped to get something more about the atmosphere, rotation time and shape of the ball at this transit than they have secured. For these important facts they must wait longer.

The Study of Astronomy Neglected —It is a surprising fact (if we are rightly informed) that less than one-half of the high schools of the United States have even the lessons in elementary astronomy taught in them. This first came to our notice, in a general way, from statistics collected for the purpose of planning a course that should be sufficiently varied and thorough for entrance to any undergraduate course of study in any collegiate institution.

When representative teachers in these secondary schools were asked why this was true, their answers, if but few in number, revealed, without doubt, the real cause. They were in substance that the study is too difficult for the high school. It belongs to the college. Or, that they do not know how to teach elementary astronomy properly, and other such like answers. It is needless to say that any person having but little interest in astronomy would be sorely tried to answer such objections if he cared to try. Is it not time that our normal schools and state institutes and other educational agencies that have to do directly with teachers gave more attention to this branch of study, instead of some other less important things?

Americans Guilty?—Here again are two small astronomical jokes which bear an obvious American impress. A tower is described as being "so high that it has to be lowered every night to let the Moon pass," and the recently discovered variation of latitude is held responsible for the fact that Alsace and Lorraine are sometimes in France and sometimes in Germany."—*Observatory*.

Yes, "an obvious American impress?" If Germany and France had only known a few years ago about Chandler's "two circular functions of different amplitudes" which explains this latitude question, they would have expected fluctuating boundaries in those countries and not had any trouble about it. But somehow they do not see it yet. When our English friends have read Hill's motion of the lunar perigee, and kindred papers, a little more carefully they will see that that tower aberration is only a bit of English lunar parallax. We have not observed it on this side of the Atlantic.

Astronomical and Physical Society of Toronto, Canada.—There was a good attendance at the meeting of February 5th. Mr. Arthur Harvey presided.

Mr. G. G. Pursey read some notes on sunspot observations, and stated his opinion that the maximum cannot be considered as yet past.. During January Mr. Pursey had noticed many interesting groups. They formed once a complete belt across the solar disc, exhibiting all the usual phenomena of more or less sudden dissolution.

Attention was called by Mr. Andrew Elvins to the fact that auroral displays predicted for January and February had materialized.

Several members had observed the paraselene of Jan 31st. That phenomenon generally called the Constantine cross was observed distinctly drawn, as it

seemed, through the Moon. One member thought the phenomenon might be produced experimentally, because it was exactly similar to the effects obtained by polarized light in the laboratory.

Some notes on meteoric showers were read by Mr Arthur Harvey, and that gentleman presented for inspection a fragment of the historic Winnebago meteor, which he had obtained through the kindness of Dr. Hahn. This stone is a typical chondrite—porous, crust rather thin, opaque black, not shining; interior color, grey, spotted with brown. On one broken surface was a thin scum of a black substance that would mark paper, presumably graphite. The metal in it is in exceedingly small globules and thin flakes, but it contributes 45 per cent of weight to the mass. There is 93 per cent iron, 6 per cent nickel and 1 per cent cobalt in the metal. Having fallen in the daytime Mr. Harvey concluded that this meteorite had passed perihelion and was coming from the Sun.

JOHN A. COPLAND.

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AISLICENUS (W. F.) Astronomische Chronologie, 8vo., cloth. Leipzig, 1895. $1.40.

Elements of Astronomy with numerous Examples and Examination Papers. By George W. Parker, M. A., of Trinity College, Dublin. Published by Messrs. Longmans, Green & Company, London and New York, 15 East 16th St. 1894. pp. 236.

This new text-book on the elements of Astronomy is especially worthy of notice because it is so different in plan from most American books of the same class. One difference is the varied and constant application of mathematical principles in definition, illustration and topical study.

If recent authors have inclined to popular statements in treating this branch generally, this one has gone as far in the opposite direction. Both methods have their advantages, but we think the careful, accurate statement, as the basis of most elemental instruction will bring best results. It should not be so formal and severely logical as to make the text dry or unattractive in style or matter. This would surely defeat one of the objects of exact expression of thought.

This author has chosen the essentials of the elements, stated and illustrated his points well and given frequent tables of numerical examples. This latter feature is a most excellent one for it gives the student some notion how he may apply his elementary mathematics and derive concrete results to illustrate the principles he is trying to comprehend. The English books in science are better than ours in this particular. This book is well and fully illustrated. The cuts mean something. On the whole it is an excellent introduction to the study of Astronomy as taught in our best colleges.